Monitoring Rangeland Health

A Guide for Pastoralist Communities and Other Land Managers in Eastern Africa

Version II

By Corinna Riginos and Jeffrey Herrick

With Contributions from Siva Sundaresan, Cary Farley, Dickson Ole Kaelo, Jeffrey Worden, and Jayne Belnap

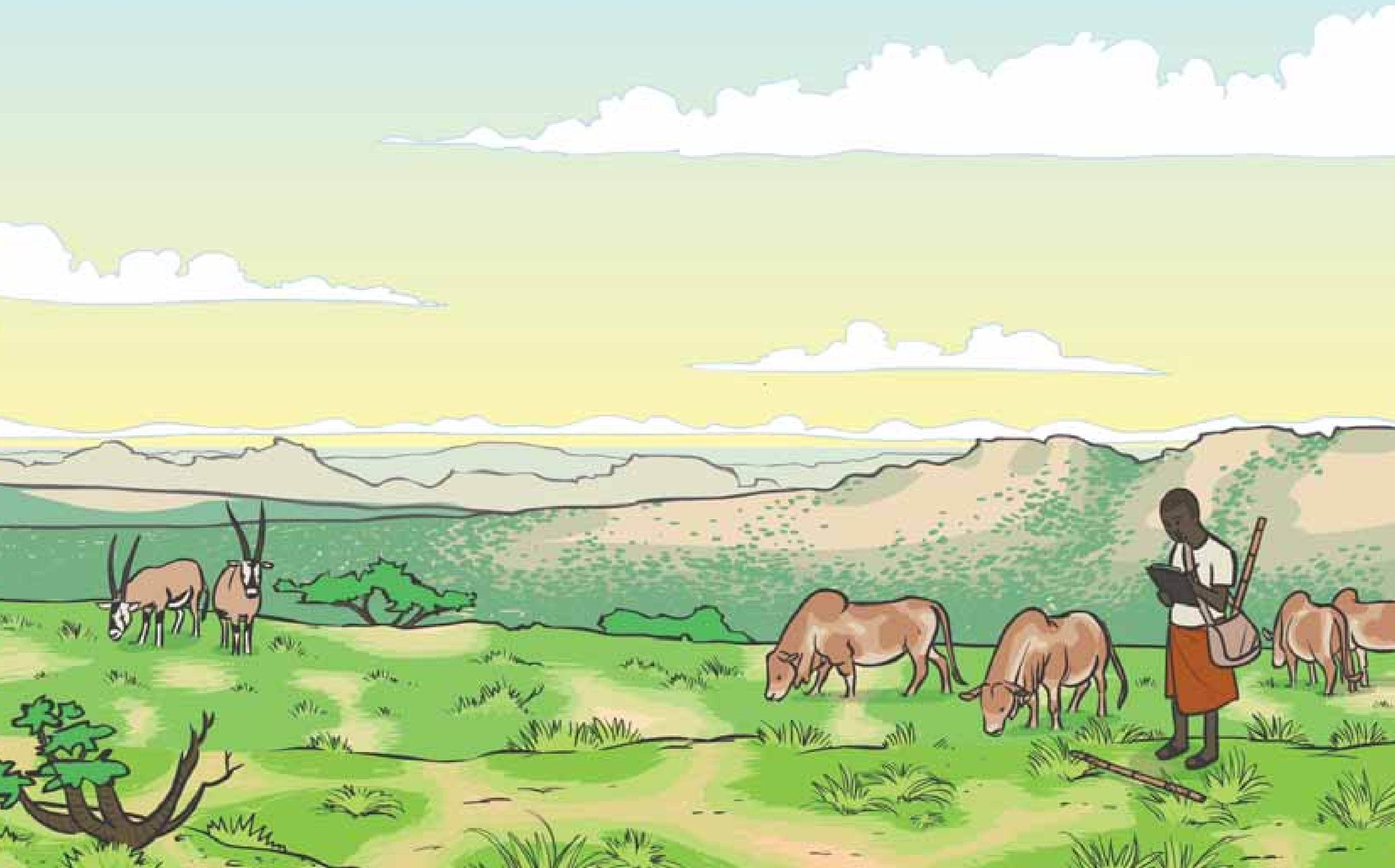

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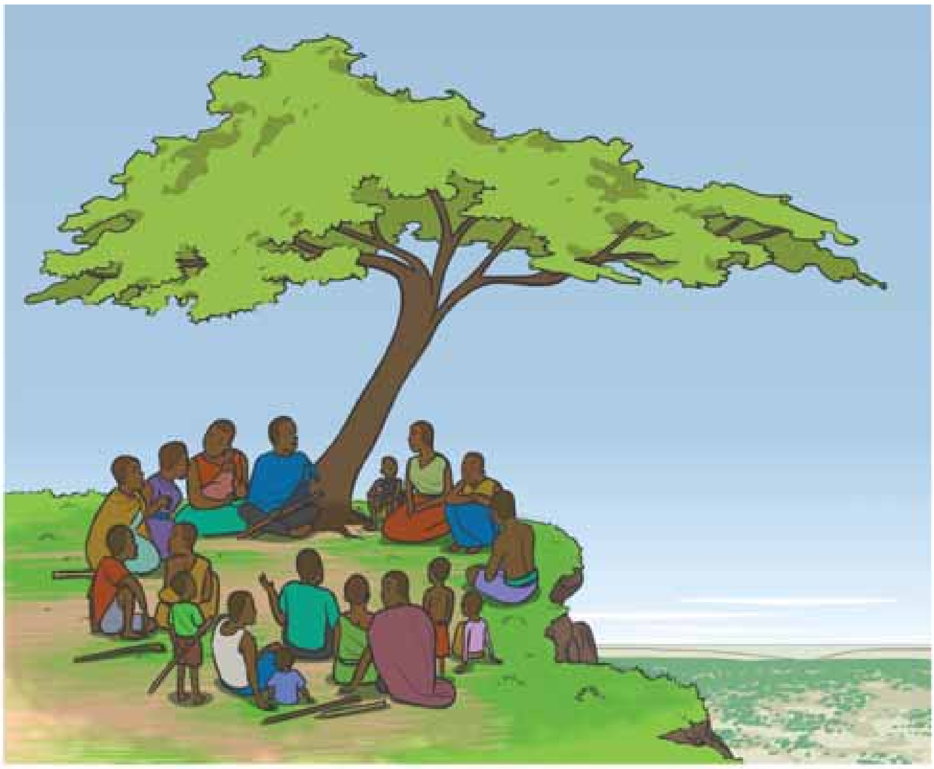
Table of Contents

Introduction and Overview

This guide is written for people who want to design and implement a simple rangeland monitoring programme in eastern Africa. In this guide, we outline a series of steps that will enable community members and other land managers to decide what, where, when, and how to monitor, as well as how to interpret and apply the results of their monitoring. We also introduce a simple set of methods for collecting monitoring data using only a pencil, a stick, and a single datasheet.

Who is this guide for?



The principles and methods introduced here have been developed for community members and other land managers who are living or working in arid and semi-arid lands, including pastoralist communities, park and conservancy managers, private ranchers, government officers, NGO staff, and researchers. We assume that the importance of monitoring is already understood by the land managers who are adopting this approach. For pastoralist communities, this means that the need for monitoring has already been established through a larger, participatory process of developing management objectives and a management plan.

Throughout this guide, we use the second person 'you' to refer broadly to the reader and the community of land managers or other stakeholders that he or she works with and/or represents. We use the singular 'you' for the sake of simplicity and readability; however, we urge the reader to be sure to involve all of the other land managers, community members, or other stakeholders in the process of developing and implementing a monitoring programme (see 'Importance of Engaging Communities and Other Stakeholders', page 11).

What is Rangeland Monitoring?

Rangeland monitoring is observing or measuring changes in the health of the land over space and time.

What is this guide for?

This guide provides monitoring tools that can be used as part of a wide variety of land management programmes, including community-led management efforts. Traditionally, many land managers and local communities have monitored their land – using local indicators – to inform their own management decisions. However, traditional knowledge systems are increasingly being eroded and disrupted, while changing environmental conditions are presenting pastoralist communities with new ecological and management challenges.

This guide is intended to build on traditional monitoring systems and support them with science-based principles and tools that will facilitate the development of a simple, sustainable, and systematic approach to monitoring long-term changes in rangeland health. We believe that the combination of local and scientific knowledge will build a more complete understanding of the critical ecological processes that need to be monitored at different locations. This, in turn, will enable land managers to decide when and where it may be necessary to modify their management practices to better meet their management goals.

The simple monitoring methods presented in this guide generate quantitative data (data with numbers). This quantitative approach can complement and add to traditional monitoring systems in a number of ways. First, quantitative information can be compared reliably from one year to the next and among different data collectors and sites. This will not only improve land managers' ability to monitor their own land, but also facilitate comparison and knowledge-sharing among different land managers as they strive to adapt to changing ecological and management challenges. Second, a quantitative approach enables information to be shared with outsiders who are not necessarily familiar with local conditions. Third, quantitative data can capture information that may be necessary for future economic diversification in arid and semi-arid lands. For example, quantitative data are often necessary to justify and place a value on payments for various ecosystem services. Finally, quantitative data, when collected from multiple sites, can be used to understand changes in the land – and the causes of those changes – that are occurring over larger scales.

The most important purpose of this guide is to present an approach to monitoring and a set of methods that will empower local managers to make sound land management decisions. Developing and using a well-designed monitoring programme is a critical step towards this end.

Why Monitor?

Monitoring rangeland health can be useful for many reasons. For example, it can help to:

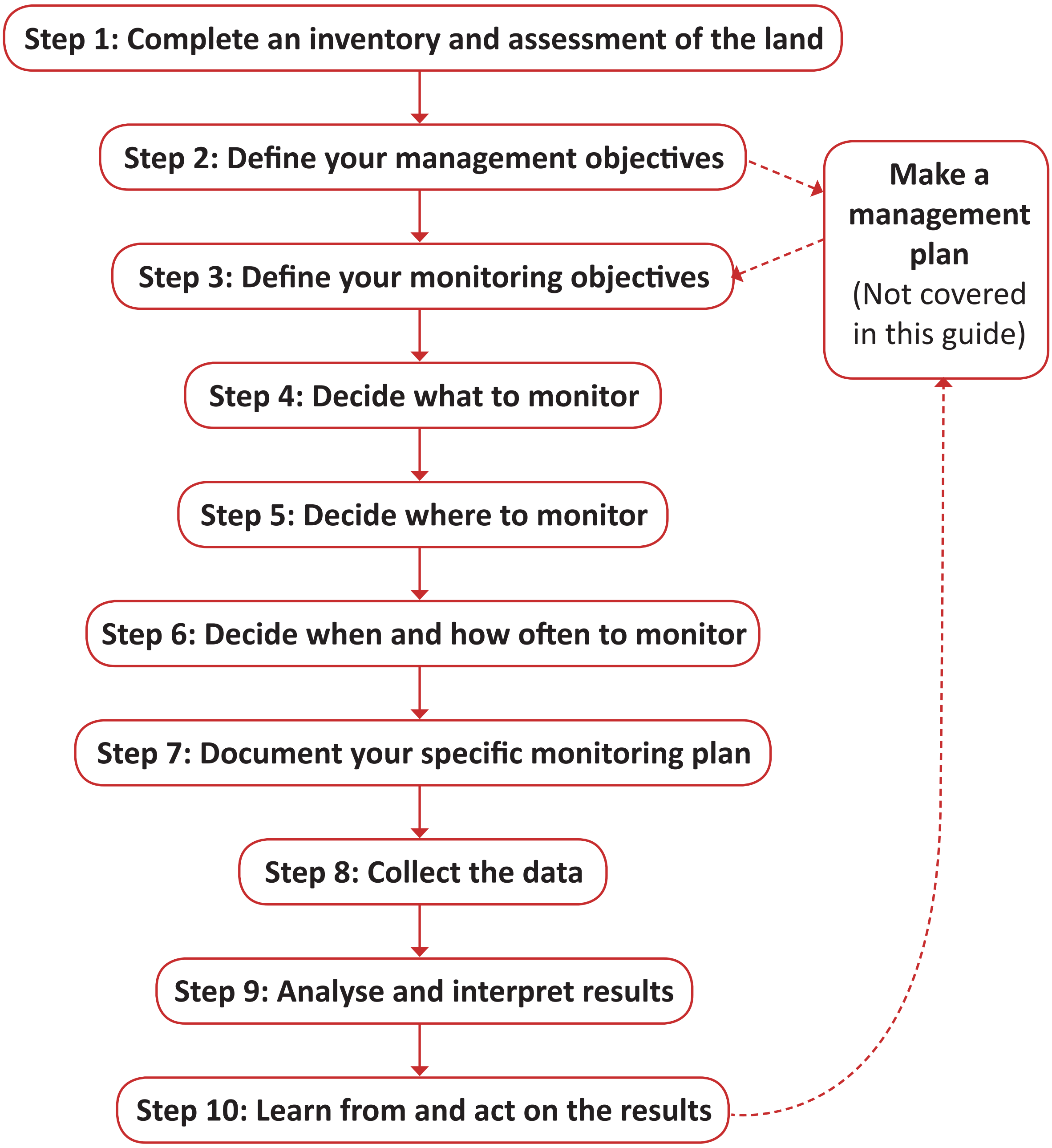
- Decide whether or not the current management is affecting the land in a desirable way. (Remember, all actions – or lack of actions – are part of 'management').
- Compare areas that are being managed differently and test new management approaches to evaluate their effects on the land.
- Notice benefits of new management approaches (when compared to other areas) before these benefits can easily be observed.
- Notice early signs of rangeland degradation before the land becomes more degraded.
- Show development partners, community members, and other interested parties that rangeland health is changing.
- Settle disputes about which management actions are working best.

Monitoring is an essential part of every management plan (see Figure 1). Monitoring allows you to evaluate the effectiveness of your management and change your management plan if it is not leading you towards your management objectives.

Figure 1: *Monitoring is part of management. By enabling land managers to evaluate the effects of their management decisions, monitoring empowers them to adapt their management and develop the best solutions for their needs.*

How to Develop a Monitoring Programme Using the Simple Process Described in this Manual

This guide will take you through the steps of designing and implementing a monitoring programme. The process includes ten key steps:



Importance of engaging community members and other stakeholders

It is important to make sure that all relevant stakeholders are fully engaged in the process of developing the monitoring programme. In particular, it is important to include all interested parties in defining management and monitoring objectives, in deciding what and where to monitor, and in interpreting and agreeing upon monitoring results. This is true for all land managers but is especially important for pastoralist communities.

Community members should not just be consulted in the design of a monitoring programme, but rather should be at the very centre of it. The monitoring programme should be built upon the knowledge and experience that pastoral communities already possess. This includes knowledge held by a wide variety of community members – including women and men, young and old, and poor and rich – about rangelands, their resources, uses, management, and traditional monitoring indicators. The data collection methods presented in this guide were developed by integrating scientific and local pastoralist knowledge and can easily be adapted to include more specific local knowledge.

Ensuring that all community members and key stakeholders are at the centre of a monitoring programme can be challenging. Without such involvement, however, the sustainability of the monitoring programme will be put at risk and the very people who are the primary caretakers of the rangeland environment marginalized. Without the full commitment, support and input of these caretakers there is little chance of a monitoring programme being usable or effective. Including neighboring communities or land managers in the monitoring and management processes is also important, as they may be facing many of the same issues and may be able to share resources to address these issues.

Key documentation providing guidance on how to encourage participation from local communities, community members, and other land managers in planning and implementing a monitoring programme is provided at the end of this guide (see 'Additional Documents and Websites', page 95).

Definitions

Management: Any actions (or lack of actions) that have an impact on the land.

Monitoring: The systematic and orderly collection, analysis, and interpretation of information about changes in land health over space and time. Monitoring is used to determine whether your management is having the effects you intended or anticipated.

Indicator: An indicator is something easy and inexpensive, but often indirect, that you can measure to observe changes in rangeland health. Indicators are what you use to monitor the land.

For definitions of other specific terms, see the Glossary (page 91).

What kind of land can I monitor?

The monitoring methods presented here are suitable for a wide variety of arid and semi-arid landscapes. This includes open grasslands or shrublands; areas with a mixture of trees, shrubs and grasses; and areas that are mostly dominated by trees and shrubs. These methods can be used for areas that are being managed for livestock, wildlife, or both.

The methods, as well as the broader approach to designing a monitoring programme, can be used for land of varying size – from a hectare-scale site, to a ranch, community area or park, to an entire watershed. In designing your monitoring programme, you will have to decide how much land to monitor. This will depend on your management objectives (Step 2) and what you want to learn from your monitoring (Step 3). You may choose to start monitoring a relatively small area of land and later expand your monitoring to cover a larger area as your experience grows or your objectives change.

How long should I monitor?

The monitoring methods presented here are meant to capture longer-term trends in land health that usually take several years to occur; they are not meant to capture changes that occur within a year, such as changes in forage availability over different seasons.

The duration of your monitoring programme will depend on your management and monitoring objectives. Some questions about land health can be answered in one to two years (for example, are there more grass seedlings in areas where grass seeds were sown?). Other questions may take several years to answer (for example, is bare ground decreasing or increasing in areas where a new management approach is being applied?). Still other questions may take many years to answer (for example, is low rainfall or are high stocking rates – or both – enabling succulent shrubs to replace perennial grasses in an area?). Generally, monitoring over many years will enable you to answer a wider variety of questions than monitoring for only a few years.

Monitoring that is carried out over many years and over large areas of land can help answer an even wider variety of questions. For instance, combining information with that of your neighbours can help distinguish what changes are due to local factors (such as grazing management, soils, or site history) versus regional changes in climate. Understanding these differences can greatly assist in future management decisions.

This guide outlines a process for designing – and using – your monitoring programme. It is important to remember that collecting data is just one small step in this process. For the results of your monitoring to be useful for management, it is essential that:

1. Your decisions about what, when, and where to monitor must be based on your management and monitoring objectives.
2. The results of your monitoring must be used to inform management decisions. Monitoring will not be useful if it is simply used to track changes in the land without acting upon the information gathered.

We strongly suggest that you read through each of the ten steps to designing and implementing a monitoring programme before you start collecting any monitoring data. Your monitoring data will be much more useful if you have already worked through the process of deciding why, what, where, and when you want to monitor.

How is this guide organised?

This guide is organised into three sections:

- Section I gives the ten steps to designing and implementing a monitoring programme, with detailed guidelines for each step.
- Section II gives a set of methods for collecting monitoring data in the field. This includes detailed instructions for each method as well as datasheets that may be copied and used in the field.
- Section III gives additional information and resources (including several additional monitoring methods) that may be useful for designing and implementing your monitoring programme.

How long will it take to design and implement a monitoring programme?

Designing your monitoring programme will take as little as one to two days, if there is a high level of consensus among all of the decision-makers and good information about the land that is going to be monitored.

The amount of time needed to collect monitoring data will depend on how many sites you are monitoring and how long it takes to travel from one site to another. Data for each site can be collected in about 20-40 minutes. If you are monitoring fewer than five sites, plan to spend one or two days per year collecting monitoring data. If you are monitoring at more sites, plan to spend several days per year collecting monitoring data.

The amount of time you need to analyse and interpret the results of your monitoring will also depend on how many sites you are monitoring. Generally, data can be analysed and interpreted in less than a day.

Section I: Ten Steps to Designing a Monitoring Programme

Step 1: Complete an Inventory and Assessment of the Land

Before planning your monitoring programme you should gather, agree upon – and, if possible, strengthen – any information about the land and its current status. Doing this will help to clarify what is being managed and provide a better understanding of where monitoring can help guide and evaluate the effects of management.

It is advisable to at least gather information on or create a map of the existing types of land, land cover or vegetation types, and current management (Step 1a). If the resources are available, gathering and mapping more detailed information about the land (Step 1b) will help you to design an even more effective monitoring programme. If, however, the resources are not available at present, you can proceed with developing the monitoring programme and plan to complete Step 1b at a later date, when it can be used to help interpret monitoring data and refine your monitoring programme.

The inventory and mapping process may draw on local knowledge, official maps, and reports (such as soil, topographic, and vegetation maps), or a combination of these resources. Participatory rangeland resource mapping – potentially complemented with GIS data and satellite imagery – can be particularly helpful for completing this step (see Box 1: 'Rangeland Resource Mapping').

Step 1a – Recommended minimum inventory

Gather and map information about these features of the land:

1. The spatial extent and/or boundaries of the land under management.
2. Different types of land. 'Types of land' or 'ecological sites' are defined by the combination of soil type, topography, and climate. Different types of land have different potentials to produce forage and also respond differently to management. For example, within a region of similar rainfall, steep, rocky areas will behave differently from sandy, flat areas or from valley bottoms with black cracking soils. (See Box 2: 'Different Sites Have Different Potentials', page 20, and 'Interpreting Site Potential' in Section III, page 84, for more about site potential).
3. Land use and management activities. This includes how the land is being used (for example, are there areas that are important grazing resources for different seasons?) as well as any management activities that are currently taking place or have taken place within the last five years.
4. Any fences, roads, settlements, and water sources (indicate temporary or permanent) on the land.
5. Different types of cover or vegetation on the land – for example, areas dominated by different species of trees, shrubs, and grasses. Often these differences are related to differences in soil type, topography, and management.

Step 1b – More detailed inventory, including assessment

In addition to the information gathered in Step 1a, gather and/or map information about:

1. More detailed classifications of different types of land. More detailed information, such as soil and topographical maps, can help with this step.
2. The long-term potential and 'reference condition' of each type of land. What does each type of land look like and function like under the best possible management? This will define the range of management objectives that is possible for a given landscape.
3. The current condition of the land relative to its potential. This will require you to complete an assessment of land health at multiple sites in the landscape.

Note: The process of completing Step 1b will benefit greatly from a combination of local knowledge (e.g. elders' memories of how the landscape looked and functioned in the past) and technical expertise. See 'Interpreting Site Potential' in Section III (page 84) as well as 'Additional Documents and Websites' (page 95) for more reading on site potential and the inventory and assessment process. The authors of this guide are currently working on an assessment guide for eastern Africa.

This photograph from southern Ethiopia illustrates two different management systems that are both on the same type of land. Inside the kalo*, or enclosure, some trees have been cut and livestock have been excluded for several seasons. Outside the* kalo*, trees have not been cut and livestock have not been excluded.*

Definitions

Inventory: The process of gathering information about the resources and features of the land being managed and monitored. Completing an inventory is useful for planning your management and monitoring programs.

Assessment: The process of evaluating rangeland health (i.e. how well critical ecological processes are functioning) at a particular site relative to the potential of that site.

Type of land: Different types of land are defined by the combination of soil type, topography, and climate. Different types of land have different potentials to produce forage and also respond differently to management.

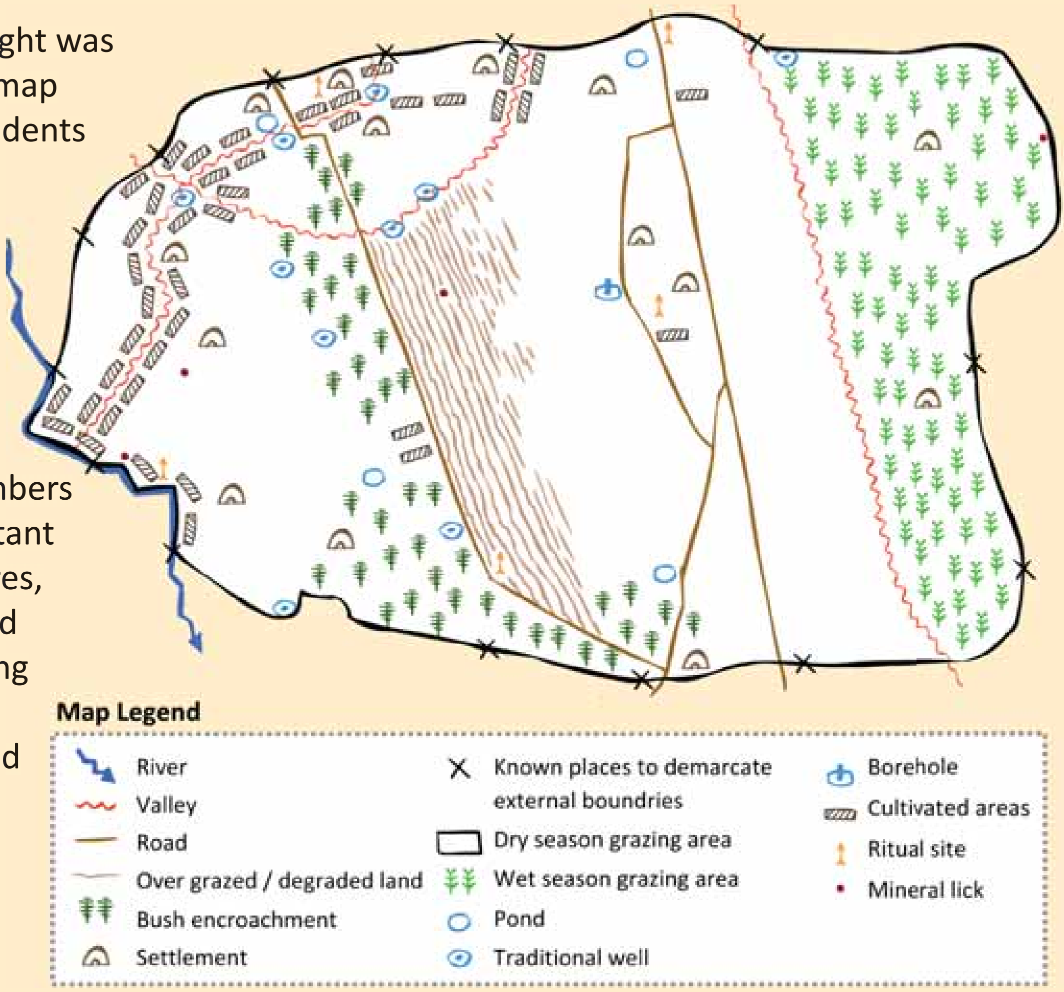
For definitions of other specific terms, see the Glossary (page 91).

Box 1: Rangeland Resource Mapping

The process of mapping rangeland resources is a powerful way to identify and understand pastoralists' (and other land managers') use of resources and access to them. Rangeland resource maps display important information such as wet and dry season grazing areas and reserves, water sources, forest boundaries, physical infrastructure (such as boreholes and markets) and other key natural resources such as fuel-wood, non-timber dryland products and mineral licks. Rangeland resource maps can also include information on land potential and land condition relative to that potential. The discussions that take place during the mapping process often help to identify rangeland management problems and challenges as well as ideas for better management in the future.

In pastoralist communities, resource mapping should ideally be led by a trained facilitator who can engage the full participation of the community. He or she should have a working knowledge of pastoralism, map-making, the participatory development process, and community facilitation. If a facilitator is not available, the community may wish to solicit input into the process from people who have access to other sources of knowledge, such as soil maps. Implementing rangeland resource mapping without these skills can create confusion and conflict.

The map at right was adapted from a map produced by residents of a pastoralist community in southern Ethiopia. Through a participatory process, community members identified important landscape features, including wet and dry season grazing areas and areas that are degraded or have a high level of bush encroachment.



For more detailed guidelines on resource mapping, see *Guidelines for Practitioners: Rangeland Resource Mapping* by Irwin and Flintan (see 'Additional Documents and Websites' on page 95 for a full reference).

Box 2: Different Sites Have Different Potentials

'Site potential' refers to what is possible at a site if it is well-managed. Different sites have different potentials, depending on the climate, soil, slope, and the site's position on the slope (whether the site is collecting or shedding water). The effects of each of these site characteristics on site potential are explained in more detail in 'Interpreting Site Potential' in Section III (page 84).

It is possible for different sites in the landscape to have the same potential but to differ in current condition. The current condition of the site (relative to its potential) depends on both current and historic management. Understanding why and how sites can differ in both their potential and their current condition relative to that potential is important for defining management objectives and designing an effective monitoring programme. However, it may not always be possible to do a full assessment of site conditions and potential before starting your monitoring programme.

This hillside has low potential since the slope is steep and the soil is very shallow with a lot of exposed bedrock. This means that water runs off quickly, so little of it soaks into the soil, and the soil cannot hold much of the water that does soak in. Even under the best possible management, this site will never produce as much forage as a well-managed site in a valley bottom where the soil is deeper and the site collects, rather than sheds, water.

Step 2: Define Your Management Objectives

Knowing what you want from the land in the long term and defining your specific management objectives will ensure that your monitoring informs your future management decisions (see Figure 1: 'Monitoring is Part of Management', page 9).

Ideally, this step should already have been completed as part of a comprehensive management planning process (see 'Additional Documents and Websites' on page 95 for more planning resources). This process should engage and include all stakeholders; the management objectives must be widely agreed-upon in order to be a successful foundation for management and monitoring plans. In this guide, we highlight the parts of this process that are essential for developing a monitoring programme.

To define your management objectives:

1. Begin by defining your long-term 'vision' for the land. What do you want the land to look like 10 or 20 years from now? What goods and services do you want it to be able to provide? Keep this description broad and make sure that it captures the objectives that the land managers and other stakeholders have for the land (See Boxes 3 and 4 for examples).
2. Define your specific objectives. How do you want your management to affect the land in the next 1, 5, 10, and 20 years? This should be as specific as possible. For example, if one of the objectives is to increase forage production for livestock, the specific objectives will depend on whether you are managing for cattle, sheep, goats, camels, or a combination of these. (See 'Examples of Common Management Objectives,' page 22).
3. If there are different objectives for different areas of the land, be sure to specify what these objectives are for each area. The objectives for each area should be agreed upon by the people using that area. Make sure that the objectives for different parts of the land do not conflict with each other.
4. Make sure the objectives are feasible and realistic based on the land's long-term potential and current condition (see Step 1: 'Complete an Inventory and Assessment of the Land'), as well as the resources available to you.
5. After both the general and specific objectives have been shared and reviewed by all stakeholders, record them in a document that everyone involved with collecting and using the monitoring data will be able to access (see Step 7: 'Document Your Specific Monitoring Plan').
6. Identify and record any management actions that are already being taken towards the management objectives. What outcomes do you expect or want from these management actions? For example, if you are doing bush clearing, what positive outcomes do you expect from the bush clearing?

Examples of common management objectives

Some common management objectives include:

- Minimise land degradation and erosion
- Maximise forage production for livestock
- Maintain or improve habitat for wildlife

These objectives should be broken down into more specific objectives, depending on your management needs and types of land. For example, if one of your objectives is to maximise forage production for livestock, what kinds of plants are desirable? Are there specific species that are not wanted? How should the land function to maximise forage production?

Box 3: Envisioning the Future – West Gate Community Conservancy

The grazing committee of the West Gate Community Conservancy in Samburu District, Kenya developed this comprehensive description of what they would like the future to look like.

How we, our land and our community must be in order to support our quality of life far into the future	
Ourselves	We must be seen as disciplined people; self-reliant/independent; action-oriented; role models
Our land	Our land must have plenty of ground cover; abundant grasslands; plenty of wild animals with diversity; revived water sources
Our community	Our community must be educated, healthy, united, development-oriented, in partnerships (with partners and neighbours), have health services nearby

Printed with thanks to the West Gate Community Conservancy and facilitators Belinda Low (Grevy's Zebra Trust) and Craig Leggett (Leggett Consulting).

Box 4: Vision from the Hilltop – Maasai Mara

Dickson Ole Kaelo relates a visioning exercise he conducted with a community group in the Maasai Mara, Narok District, Kenya:

Early in the morning, ahead of a scheduled community meeting, a representative group of community members walked up a nearby hill. From a vantage point overlooking the land that they intend to manage as a livestock grazing area and wildlife conservancy, they held a discussion based on the following questions:

- What did the land, the forests, the hills, the riverine vegetation, the wooded areas or open plains, human settlements and other land use activities look like twenty years ago?
- What do these features look like today?
- What caused the changes?
- What are the implications of these changes for the people, livestock, wildlife, and the value of the land?
- If these changes continue for the next twenty years, what will the land look like? Is this desirable?
- What landscape features would the community like to leave for their children?
- What needs to be done to achieve this desirable state, and what observable indicators could show that the desirable state is being attained?

An open discussion was held where participants shared their views and perceptions, and the outcomes were presented at a larger community meeting for further discussion.

The outcome of this discussion was a general feeling that forests are being lost to charcoal burning, the hills are covered by dense shrubs that are replacing tall trees, grass height now remains short even after the wet season, and the two rivers flowing through the land are drying up while the water that remains has become murky. Cows are finding little to eat and drink, and wildlife has since disappeared except for plains zebra. Some landowners have sold land and many more are contemplating selling more land, leading to fragmentation of the landscape.

It was agreed that this state of the land was undesirable and action must be taken to arrest the situation. It was further agreed that collective responsibility must be taken so that the community can work together towards achieving a more desirable future landscape.

Monitoring is what you use to evaluate the direction in which your management is going. For monitoring and management systems to work, you need to know what direction you want to go (management objectives – Step 2) and what you need to know to stay on course (monitoring objectives). Defining your monitoring objectives is thus essential to designing an effective monitoring programme. It is important to recognize, however, that your monitoring objectives can change over time and that you may periodically need to revisit, refine, and/or update your monitoring objectives.

To define your monitoring objectives:

1. Decide:
    a. What do you want to learn from your monitoring?
    b. Are there management or restoration activities you want to monitor to learn what effects they are having on the land?
    c. Are there areas you are concerned about – such as areas where the risk of degradation is high – that you especially want to monitor?
    d. Do you want to monitor changes over the whole landscape or changes in specific areas that are likely to change within a few years? Or both?
2. Revisit your monitoring objectives after you have worked through Steps 4, 5, and 6, below (what, where, when, and how often to monitor). Make sure you can achieve your monitoring objectives. Also, be sure that your monitoring objectives will help you meet your management objectives.

Examples of common monitoring objectives

Most monitoring objectives set out to answer a specific question about the effects of a specific type of management (identified in Step 2) on one or more types of land (identified in Step 1). For example, by:

- Comparing areas where you are trying different management approaches – such as bush clearing, fire, various grazing regimes, or reseeding – with each other or with areas where no new management approach is being tried out.
- Comparing how well a management system works on different types of land to learn where that management system will be most effective.
- Monitoring changes in specific, target areas that you think might change more quickly than the rest of the landscape or are particularly important areas in the landscape.
- Monitoring changes in the landscape as a whole (or in the most common or most important areas in the landscape) to determine when a change in management system is necessary.

Step 4: Decide What to Monitor

Your decisions about what to monitor should be based on both your management and monitoring objectives. If you have completed an assessment of current conditions on the land (Step 1b), you can also use this information to identify the kinds of changes in the land you are most concerned about.

It is not necessary to measure your progress towards each objective directly; instead you can measure a few key indicators of how the land is functioning (for example, capturing and storing water for plant growth or limiting soil loss). This guide focuses on evaluating how well the plants, water, and soil are functioning because almost all land uses depend on the health of these essential 'foundation blocks' of the ecosystem (Figure 2; see also 'Why Monitor Plants, Water, and Soil?' in Section III, page 79). The methods described here (and in more detail in Section II) were selected because they generate indicators that are *necessary* for nearly all management and monitoring objectives and are *sufficient* for most.

In most cases, these indicators capture information about changes in the land that people are already observing informally (see Box 5: 'Community Members Describe Changes in The Land'). However, you may find there are additional indicators you would like to monitor to evaluate your progress towards your management objectives. It is also useful to periodically revisit and update your decisions about what to monitor.

To decide what to monitor:

1. For each management objective:
    a. What observable changes in the land will indicate that you are meeting your management objectives?
    b. Are there 'early-warning' indicators – changes that will occur within a short period of time (one to three years) – that you are meeting or not meeting these objectives?
2. Use Table 1 ('Core Indicators') and Figure 3 to help choose the indicators you want to monitor. This table and figure provide more information about the suggested indicators and how they relate to the functions and services you may want the land to provide.
3. Use Table 2 ('Suggested Indicators for Three Common Management Objectives') to help prioritize which indicators to monitor, depending on your management objectives.
4. Decide which methods you want to use, based on the indicators you have selected (see Table 1: 'Core Indicators'). An example of how to choose indicators and methods is given in Box 6: 'Participatory Indicator Selection - Kalama Community'.
5. Decide whether there are any specific plant species you want to monitor for changes in cover and/or density. These may include 'good' (desirable) and 'bad' (undesirable) species, as well as other 'key species' of particular interest. Record these species in a document that can be referred back to in the future (see Step 7: 'Document Your Specific Monitoring Plan').

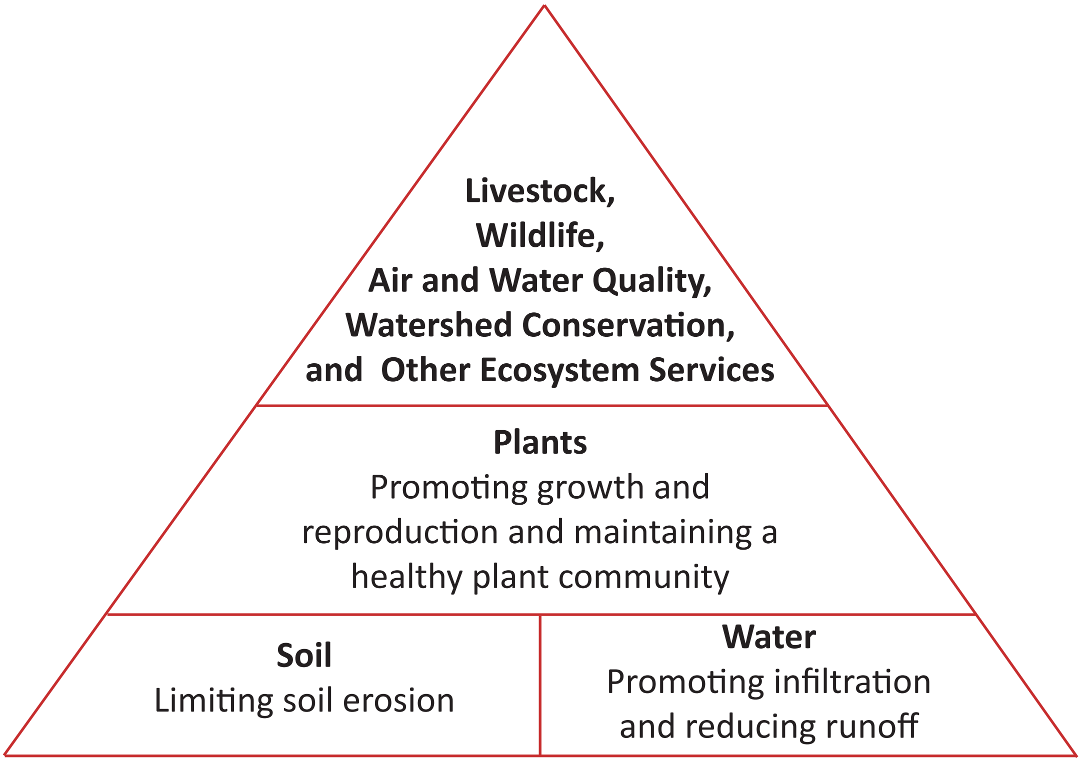


Figure 2: *Soil, water, and plants are the 'foundation' supporting everything else that you might want from the land. By monitoring indicators that tell you about the health of the soil, water, and plants, you can evaluate how solid this foundation is. See 'Why Monitor Plants, Water, and Soil?' in Section III, page 79, for more details.*

Basic Site Information

In addition to collecting data on the indicators you have chosen, we strongly suggest that you also plan to collect some basic information about the soil, slope, and vegetation at each monitoring site (see Section II for more details). This information only needs to be collected the first time that you visit each monitoring site. Basic site information will help you to interpret the results of the monitoring and make sure that you are comparing similar sites.

Box 5: Community members describe changes in the land

The methods presented in this guide provide a systematic way to collect information about changes in the land that many people already observe and monitor informally. Here, community members from around Kenya and Ethiopia describe some of the changes they have seen:

"Now the only kinds of plants growing are the ones that grow faster during the short rains." – Albert Kuseyo, Ol Kiramatian Community, Kajiado District, Kenya – observing that there are now fewer perennial grasses and more annual grasses.

Increasing density and cover of undesirable plants, such as this Sansevieria*, are often signs of degradation.*

"Before, the water was sinking into the land. Now it is washing over it." – Robba Bulga, Karayu Community, Awash Fentale District, Ethiopia

"Where there used to be open places, it is now bushy with lots of bare soil within those areas." – Jackson Letoiye – West Gate Community, Samburu District, Kenya

"The cattle paths to the river became gullies." – Lela Kinyaga, Chairman of Natural Resources Committee, Il Ngwesi Community, Laikipia District, Kenya

More bare ground means more erosion and nutrient loss and less forage for livestock and wildlife.

Water can flow quickly and cause erosion in places where there are large gaps between plants.

Table 1: Core Indicators

We suggest a set of core indicators that can be measured using four simple methods. Each of the four methods is presented in more detail in Section II.

Indicator	Description & Relationship to What You Want Landscape to Provide	Method
Amount of bare ground	More bare ground (soil that is not protected by live or dead plant material, rocks, or lichen) means more erosion, fewer plant nutrients, and less forage for livestock and wildlife.	Plant and ground cover*
Plant basal cover	More plant bases (places where plants are rooted to the ground) means less risk of runoff and erosion. Basal cover is also a good indicator of long-term forage availability since it does not change with rainfall nearly as much as plant canopy cover does.	Plant and ground cover
Perennial grass cover	Most managers want more of the ground to be covered by perennial grass canopies, as this means more forage for livestock and less erosion. In some cases, it may be useful to divide perennial grasses into 'good' and 'bad' species.	Plant and ground cover
Tree and shrub cover	Most managers want more cover of 'good' trees and shrubs (which provide forage to browsing livestock, such as goats and camels) and less cover of 'bad' trees and shrubs (problem species, such as *Acacia reficiens*, *Prosopis*, or *Opuntia*).	Plant and ground cover
Tree and shrub density	Tree and shrub density, together with tree and shrub cover, tells managers whether they are getting more 'good' or 'bad' trees in the landscape. Increasing seedling density is a good early-warning indicator that tree cover is going to increase in the future.	Plant density
Gaps between plants	When plants are close together, water and wind cannot pick up enough speed to carry the soil away. Instead, water soaks into the ground and wind has little effect. Plant bases slow the flow of water, while plant canopies slow wind erosion. (See Figure 4 on page 67).	Gaps > 1 m between plants
Plant height	Different species of wildlife and livestock prefer different heights of trees and grasses. Plant height, together with gaps between plants, can be used to measure changes in vegetation structure.	Plant height

*The 'plant and ground cover' method can also be used to monitor changes in the amount of ground covered by litter and lichen.

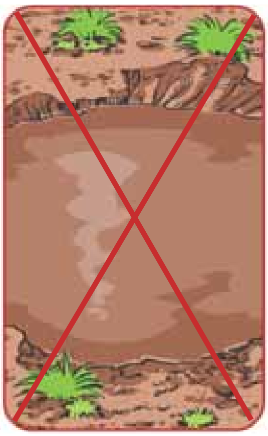
What you want the landscape to provide
Forage and habitat for livestock and wildlife; other ecosystem services

What the landscape needs to do
Keep soil and water for plants to grow and clean water for people and animals to drink

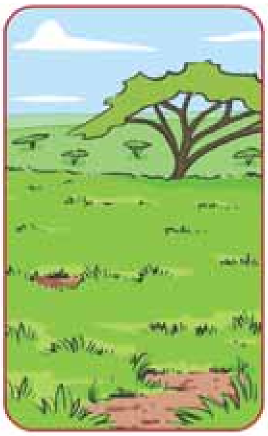
What you want the landscape to look like
For example, grass with some trees

Desirable landscape:

Undesirable landscape:



Desirable landscape:



Undesirable landscape:

Indicators:
Plant cover; bare ground; gaps between plants

Indicators:
Plant cover for different types or species of plants; plant height; tree and shrub density

Methods:

Plant and Ground Cover

Gaps >1 m Between Plants

Plant Height

Plant Density

Figure 3: *The four suggested monitoring methods can generate indicators that tell you about changes in what the landscape looks like and what services it provides.*

Table 2: Suggested Indicators for Three Common Management Objectives

Not all indicators are important for every management objective. This table provides suggestions about the relative importance of these indicators for each management objective. You can also fill in additional management objectives and indicators in the blank spaces. The indicators are described more fully in Table 1: 'Core Indicators'.

Management Objective	**Indicator**							
	Amount of bare ground	Plant Basal Cover	Perennial grass cover	Tree / shrub cover	Tree / shrub density	Gaps between plants	Plant height	Other:
Minimise land degradation and erosion	High	High	High	Medium	High	Medium	Low	
Maximise forage production for livestock	High	High	High	High	Low	Medium	Medium	
Maintain or improve habitat for wildlife	High	High	High	High	High	High	High	
Other:								

Box 6: Participatory Indicator Selection – Kalama Community

The Kalama Community's experience illustrates the process of setting management objectives and priorities and selecting indicators to evaluate their progress towards meeting those objectives. The grazing committee of the Kalama Community Wildlife Conservancy (Samburu District, Kenya) has identified three key management objectives, as well as indicators of success in meeting these objectives and early-warning indicators of failure to meet these objectives. In parentheses, we suggest methods that could be used to measure these indicators. These methods are introduced in Table 1: 'Core Indicators'.

Management Objective	Indicators of Success	Early-warning Indicators of Failure
Reduce bush encroachment	• More open habitat • Increased proportion of useful trees and shrubs	• More seedlings of *Acacia reficiens* • *Commiphora* appearing in new areas • More bare ground
	(Methods: plant and ground cover; plant density)	(Methods: plant (seedling) density with *A. reficiens* and *Commiphora* as key species; plant and ground cover)
Increase grass cover and available forage	• Reduction in bare ground • Increase in grass cover • Increase in grass height • Increase in cover of palatable grass species • Increase in cover of palatable herb species	• Reduction in cover of palatable grass species, e.g. *Chrysopogon* species and *Leptothrium senegalense* • Increase in bare soil • Increase in less palatable grass species, e.g. *Aristida* species
	(Methods: plant and ground cover with palatable plants as 'good' plants; plant height)	(Methods: plant and ground cover with palatable plants as 'good' and unpalatable plants as 'bad' plants)
Reduce erosion	• Gullies start closing up • Decrease in water run-off • More pools of water on surface after rain • More leaf litter remains behind after rain (no litter dams)	• Increase in gully size (width, length, depth) • New gullies forming • Increased water runoff
	(Methods: plant and ground cover; gaps >1 m between plants; observational indicators)	(Methods: gaps >1 m between plants; observational indicators)

Table adapted from *Developing Participatory Rangeland Monitoring and Management* with thanks to the Kalama Community, Juliet King, Guy Parker, Dominic Lesimirdana, and Northern Rangelands Trust.

To decide where to monitor, you must first choose general monitoring areas based on your monitoring objectives (Step 5a), and then choose specific monitoring sites within those monitoring areas (Step 5b).

Step 5a: Choosing 'Monitoring Areas'

1. Refer back to the information and maps you gathered in Step 1 ('Complete an Inventory and Assessment of the Land'). What are the important management areas or resources on the land? What are the important types of land, vegetation, or habitats? What kind of condition are these different areas in relative to their potential?
2. Revisit your monitoring objectives. Do you want to monitor specific areas or the landscape as a whole? Do you want to compare the effects of a new management system (or systems) to the existing management system? Do you want to monitor the effects of one management system on two (or more) different types of land?
3. Based on your answer(s) to these questions, decide which of the following three options to follow. Many monitoring programmes will include a combination of two or even all three of these options.

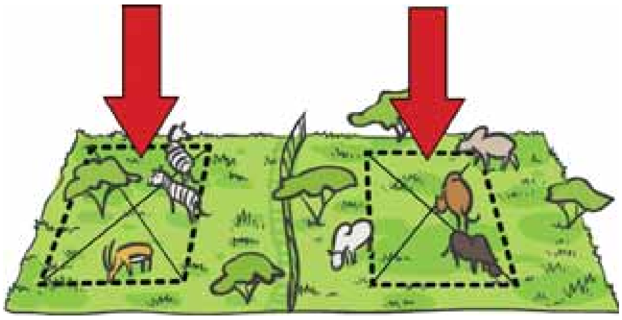
Targeted areas: Use this approach if you want to monitor change in specific, targeted areas. Targeted areas could include areas that are particularly important or unique in the landscape, or areas that are particularly sensitive (areas that have a high risk of rapid degradation or high opportunity for rapid recovery). To use this approach:

1. Designate a separate monitoring area for each targeted area.
2. Identify the type of land and management system for each targeted area. This will be useful for interpreting the results of your monitoring.

Landscape as a whole: Use this approach if you want to monitor general changes over a large area of the landscape. To use this approach:

1. Designate a separate monitoring area for each combination of type of land and management system or management objective. It will help to map these areas, if you have not done so already.
2. Decide whether there are some areas you do not want to monitor. These could include land or vegetation types that are not common or not very important in the landscape.

Comparing different areas: Use this approach if you want to compare two (or more) different monitoring areas. For example, you might want to compare the effects of different management systems to learn which system is working best (remember that every part of the landscape is being 'managed'). Or you might want to compare how well a particular management system works on different types of land. In both cases, using a comparison approach is very valuable because it helps you to determine whether changes in land health are being caused by management rather than other factors (such as climate — see Box 7: 'Rainfall Variability and the Importance of Comparison'). To use this approach:



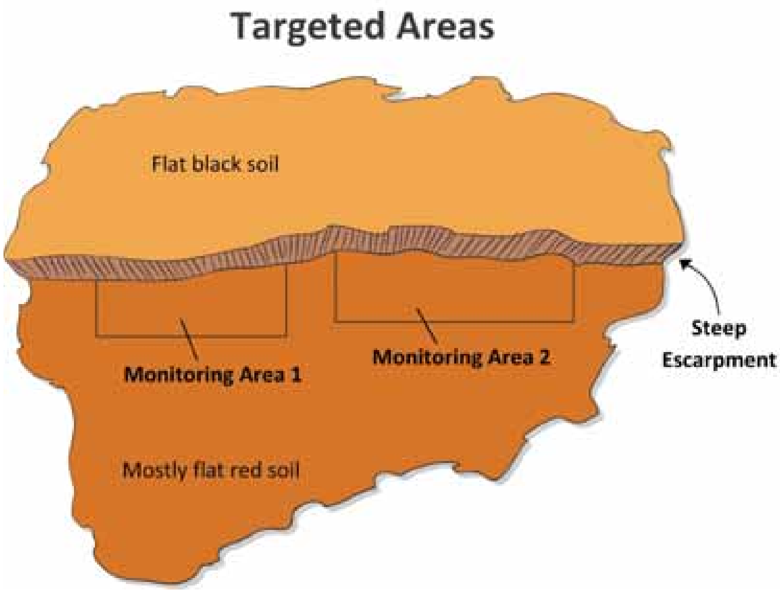
1. Designate a separate monitoring area for each combination of type of land and management system. It will help to map these areas, if you have not done so already.
2. For comparing the effects of two (or more) different management systems, only compare monitoring areas that occur on the same type of land.
3. For comparing the effects of management on two different types of land, only compare monitoring areas that have the same management system.
4. Be careful not to compare two areas under different management systems if you have very different management objectives for those areas. For example, it does not make sense to compare the effects of cutting trees in an area for which your management objective is to reduce tree cover with the effects of planting trees in an area for which your management objective is to increase wood production.

Once you have chosen your monitoring areas based on one or more of these approaches, give each monitoring area a unique name and note in your monitoring plan which areas (if any) will be compared to each other (see Step 7: 'Document Your Specific Monitoring Plan').

Examples of how to designate monitoring areas

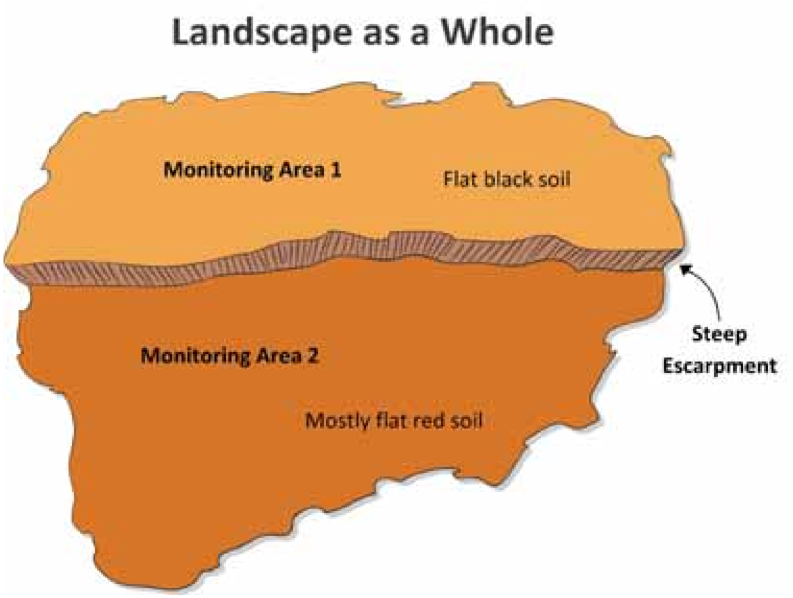
Example 1: Targeted areas

In this example map (right), two areas at the base of a steep escarpment have been chosen for monitoring. These areas were chosen because they have (a) a high risk of erosion, and (b) high potential forage production. These areas have both high risk and high potential because they receive a lot of water runoff from the escarpment. Each targeted area has been designated as a separate monitoring area.



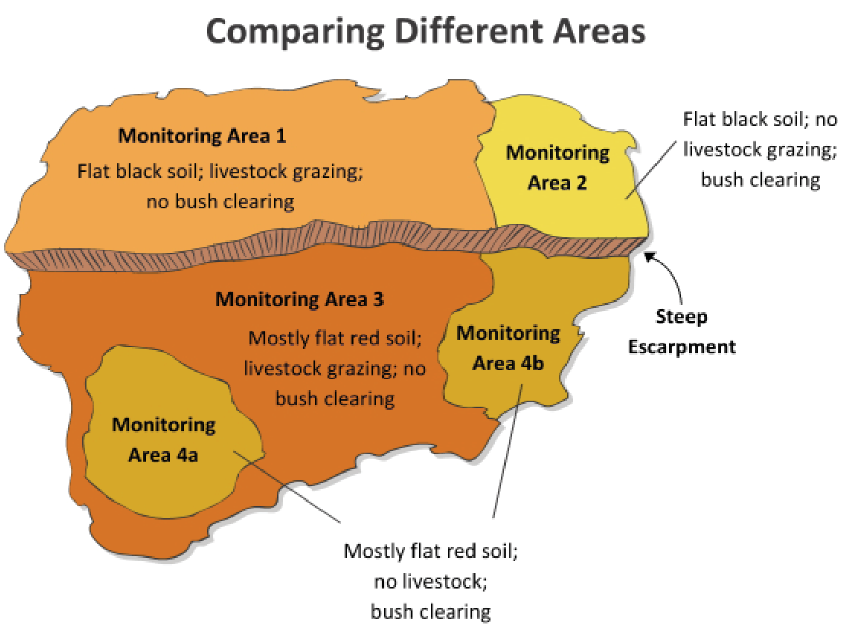
Example 2: Landscape as a whole

In this example map (right), there are three different types of land: black soil that is flat; red soil that is mostly flat; and a steep escarpment area that is the boundary between black and red soils. The land managers have decided not to monitor the steep escarpment because it only makes up a small part of the landscape, is relatively inaccessible to livestock and most wildlife, and supports very little forage production. Each of the other two types of land (red soil and black soil) has been designated as a separate monitoring area.



Example 3: Comparing different areas

In this example map (below), there are three different types of land: black soil that is flat; red soil that is mostly flat; and a steep escarpment area that is the boundary between black and red soils. There are also two different management systems: livestock exclusion with bush clearing, and livestock grazing with no bush clearing. Both of these management systems are present in both the black and red soils. As a result, the land can be divided into four different monitoring areas. (Note that Monitoring Area 4 is made up of two sub-areas that share the same type of land and same management system). To compare the effects of the different management systems, you would compare Monitoring Area 1 with Monitoring Area 2 and (separately) Monitoring Area 3 with Monitoring Areas 4a and 4b. To compare the effects of the same management system on different types of land, you would compare Monitoring Area 1 with Monitoring Area 3 and (separately) Monitoring Area 2 with Monitoring Areas 4a and 4b.

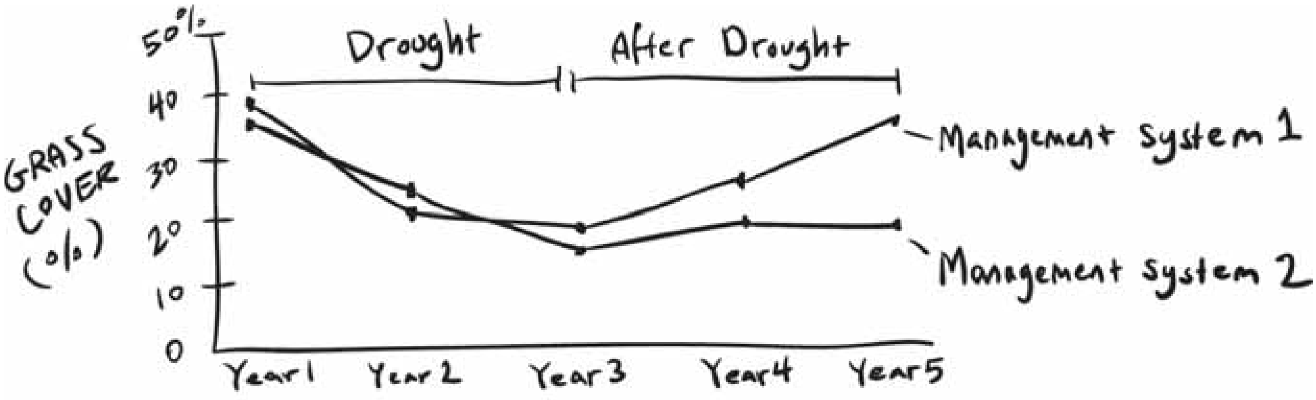


Box 7: Rainfall Variability and the Importance of Comparison

Sometimes highly variable rainfall can make it difficult to determine whether you are achieving your management objectives or not. For example, grass cover might decline over several dry years but recover after one or two wet years. If you were trying out a new management approach and only happened to monitor the change in grass cover in this management area during the drought years, you might mistakenly conclude that the management approach was not working well.

The **comparison** approach can help to separate the effects of rainfall variability from management. When you compare the changes in two management areas over time, you can see which management type is working better – even if both management areas are also changing in response to rainfall.

For example, in the figure below, grass cover under Management System 1 recovered after several years' drought, whereas grass cover under Management System 2 did not recover well after the drought. This suggests that Management System 1 is working better than Management System 2.



Step 5b: Choosing specific locations for 'monitoring sites' within monitoring areas

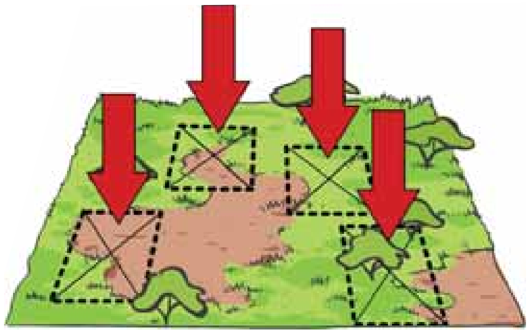
Once you have chosen monitoring areas, the next step is to locate specific monitoring sites within those monitoring areas. You can use **randomly located sites**, or choose **representative sites.**

Randomly located sites are sites that you choose without necessarily knowing anything about the sites ahead of time. For example, you could locate them first on a map, scattering the sites around the monitoring area.

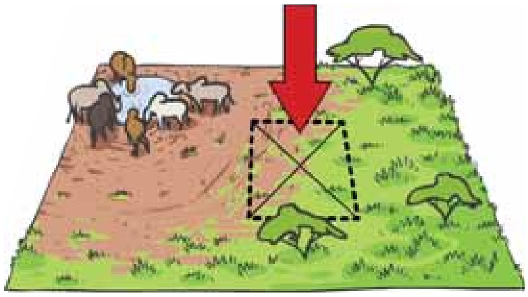
Representative sites are sites that you hand-pick to represent typical conditions within the monitoring area. For example, a representative area might be close enough to water to be used frequently by wildlife and livestock, but not so close that it is heavily impacted and more degraded than most of the landscape. To choose good representative sites, you must have a good knowledge of the monitoring area and the conditions found within that area.

To decide how to locate monitoring sites:

1. Use **randomly located sites** within each monitoring area if:
    a. Your monitoring areas are relatively small (less than 100 hectares each), or
    b. Your monitoring areas are large and you are not confident that you can choose representative sites for those areas



2. Use sites you consider to be **representative sites** if:
    a. Your monitoring areas are large, and
    b. You can only monitor a few sites in each monitoring area, and
    c. You are confident that you can identify areas that are (and will continue to be) representative of the monitoring area



3. Include as many ‘replicate sites’ in each monitoring area as possible (see Box 8: ‘Replicating Monitoring Sites Within Each Monitoring Area’), regardless of which method you use to locate your sites.

Additional guidelines for locating monitoring sites:

1. Make sure the monitoring sites are not all next to each other. Spread them around within the monitoring area to make sure you get a good representation of that area. Choosing sites randomly will help.
2. However, do not select sites where the slope, soil, and vegetation type are very unusual for the area you are monitoring.
3. Avoid putting the monitoring sites near rivers or streams, since the vegetation is usually different in these areas – unless you specifically want to monitor changes in these areas.
4. Avoid putting the monitoring sites very close to bomas, settlements, or water points – unless you specifically want to compare those areas to other areas.
5. Avoid putting the monitoring sites too close to major roads. Ideally, the monitoring sites should be at least 100 m from any major road.

Definitions

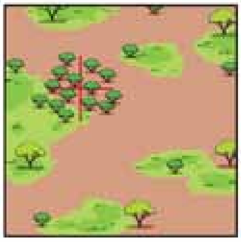
Monitoring area: A general area you have designated for monitoring, based on your monitoring and management objectives.

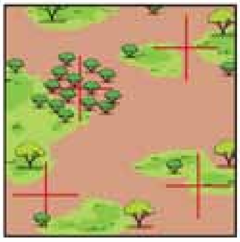
Monitoring site: The specific sites at which you collect monitoring data. Each monitoring area should have several specific monitoring sites in it.

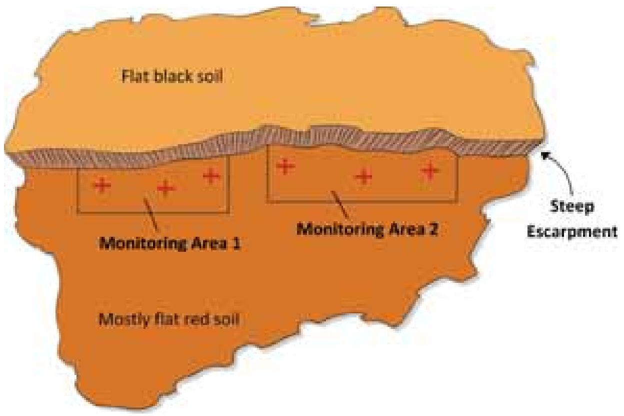
For definitions of other specific terms, see the Glossary (page 91).

Box 8: Replicating monitoring sites within each monitoring area

Try to collect data from three or (ideally) more monitoring sites monitoring sites within each monitoring area. This is important because most landscapes are very patchy. If you collect data from only one site, you risk choosing a site that is not representative of the whole landscape. By collecting data from at least three monitoring sites, you can be more confident that your results reflect what is happening within each monitoring area. Use the maps you gathered or created in Step 1 ('Complete an Inventory and Assessment of the Land') to help locate your monitoring sites within each monitoring area. In general, the more sites you can collect data from, and the farther they are spaced apart within each monitoring area, the better.

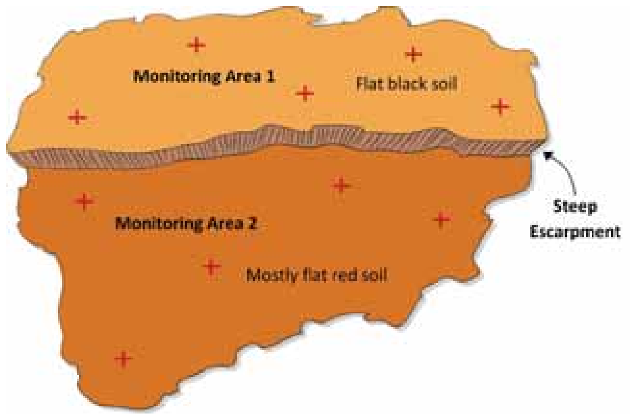


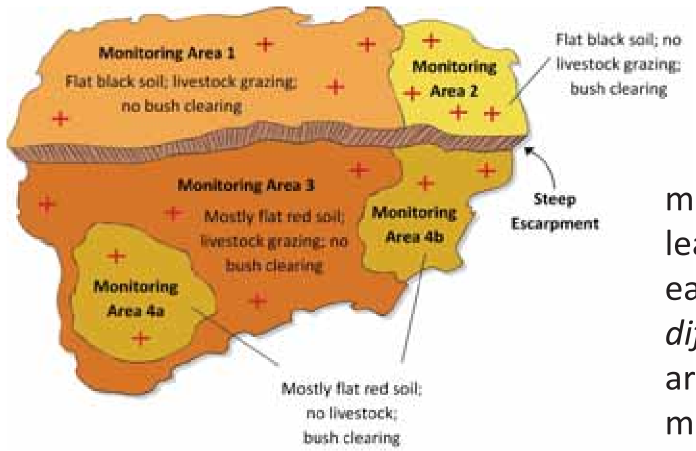




If you are monitoring several targeted monitoring areas, locate at least three monitoring sites within each of these targeted monitoring areas.

If you are monitoring a large landscape that is made up of several different types of land, locate at least three monitoring sites within each type of land. Monitoring areas are defined by the different types of land.





If you are comparing two different management systems, locate at least three monitoring sites within each management system *in each different type of land*. Monitoring areas are defined by the combination of management system and type of land.

How often to monitor

This guide focuses on changes in rangeland health, which usually take at least one year to occur; it does not focus on seasonal changes in forage availability. To monitor changes in rangeland health, we suggest that you monitor every one or two years.

In some cases, you may need to monitor less frequently in order to monitor more sites. For example, you could monitor half of your sites every year, so that each site is monitored every two years.

When to monitor

Deciding when to monitor can be especially challenging in environments with highly variable rainfall. If you are monitoring once a year, try to collect your data during the same season each year. The end of the rainy season is the best time of year for identifying plant species and observing signs of erosion. The dry season is the best time to observe changes in the percentage of large gaps between perennial plants. Collecting data during the same season is more important than collecting it on exactly the same date each year. However, if you usually collect data during the rainy season and the rains fail, you should still collect the data so that you are monitoring at least once every one or two years.

Step 7: Document Your Specific Monitoring Plan

Maintaining a written description of the monitoring plan is important for the following reasons:

1. It provides a guide for others to follow so that they can collect data in the same way in the future, using the same methods at the same sites and at the same time of year. This is necessary so that data that has been collected at different times or by different people can be compared.
2. It helps others to understand how and why you collected the data you collected, so that they can learn from it.
3. It is necessary for interpreting and making sense of the data.

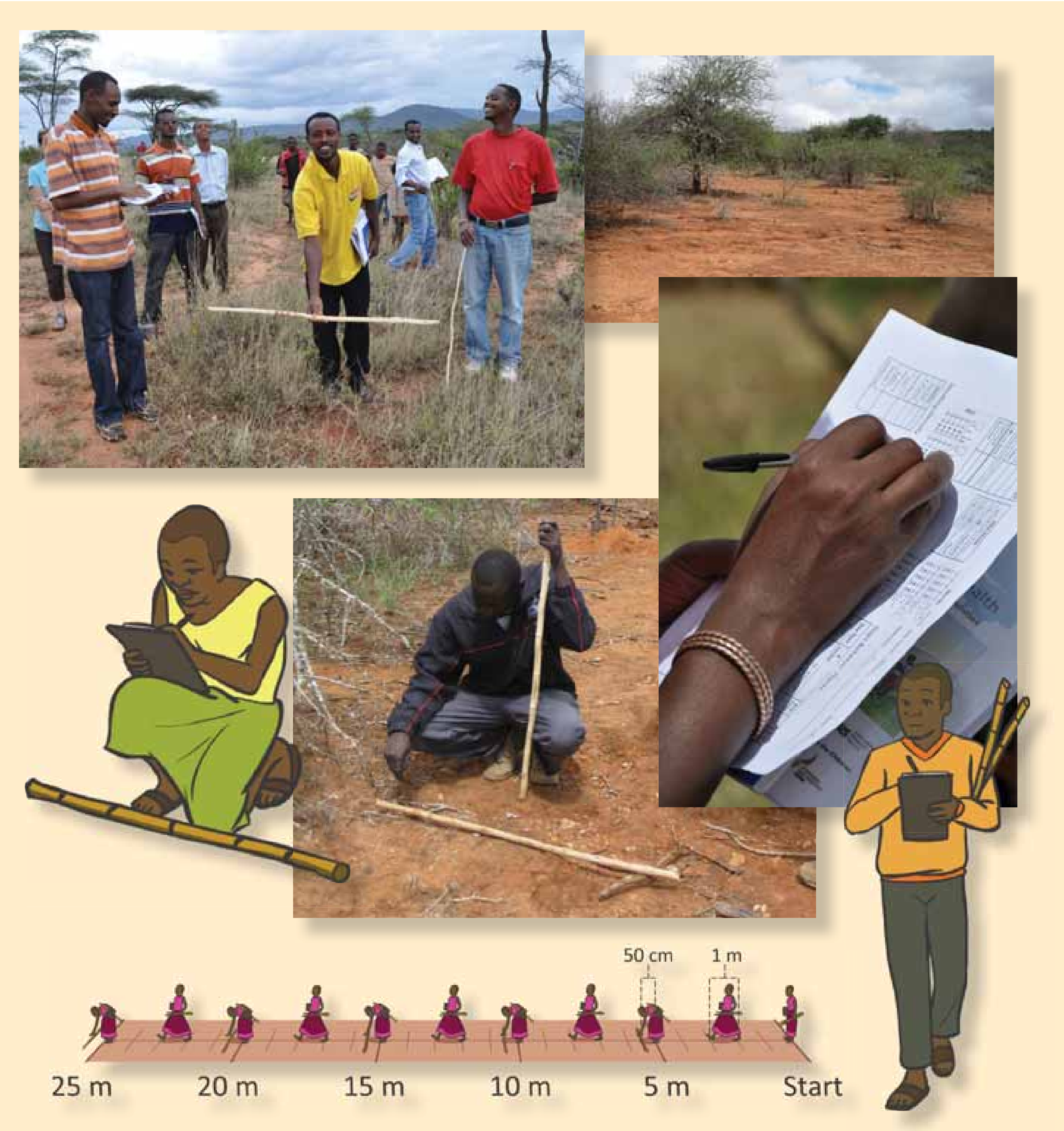
The monitoring plan should include:

- The name of the monitoring plan or programme (including the name of the land, property, or area being monitored)
- Any maps or other materials put together as part of the inventory and assessment
- Monitoring and management objectives
- Monitoring methods that will be used, and any modifications to the methods
- Indicators that will be calculated from the methods
- Other indicators that will be observed
- Monitoring areas, including any monitoring areas that will be compared with each other
- Monitoring sites at which the data will be collected (including, if possible, a map, GPS coordinates, and/or a written description of the monitoring sites and how to find them)
- Which monitoring sites will be treated as replicates within each monitoring area
- When and how often data will be collected
- Who will collect the data
- Where the data will be stored (including a location for a second copy of all data)
- Who will have access to the data, and how they will be able to get the data
- What materials will be prepared to share the monitoring results with other community members or stakeholders
- What process will be used to ensure that the results reach all of the interested parties

Once the monitoring plan has been documented, it should be presented to the whole community of stakeholders, land managers, or other decision-makers, giving them a chance to fully understand, review, and agree upon the plan. Community members as well as any facilitators should both keep a copy of the monitoring plan and work together to keep the monitoring consistent over multiple years.

Step 8: Collect the Data

After planning and documenting all the details of the monitoring plan, it is time to start collecting the data. Section II (pages 49-75) provides detailed instructions for collecting data on plant and ground cover, gaps between plants, plant height, and plant density. These methods are simple and quick, requiring only a 1 m-long stick and a datasheet. Section II also provides instructions for collecting some basic site information and observational data that will be helpful for interpreting the results of the monitoring.



Analysing and interpreting the results of your monitoring involves three steps: analysing the results by comparing changes in critical indicators across years, monitoring sites and monitoring areas; presenting these results to all of the interested stakeholders; and interpreting what these changes might mean – making sure that all community members, land managers, and other stakeholders are informed and in agreement about the interpretation of the results.

Analysis

1. For each indicator, decide what the changes will mean and what decisions you will make based on those changes. What changes will tell you whether you are meeting your management objectives? This could include both the direction of change (positive or negative) and the amount of change (for example, 25% decrease in bare ground).
2. Decide which monitoring sites you are going to group as replicates. See Box 9: 'Replicates and Averaging' for more information.
3. Examine the basic site information you gathered for each monitoring site. Make sure that all the sites that are being grouped as replicates (and being compared, if you are comparing different management systems) are similar to each other in terms of soil (texture and colour at all three depths), slope, landscape position, and vegetation type. If one of the sites is different from the others, do not include it in the analysis.
4. Examine the observational indicators of site use you gathered at each monitoring site. If any of the sites experienced an unusual level of use (high or low) for that management system, you may not want to include it in the analysis.
5. For each indicator, calculate the average for all of the replicate sites in each monitoring area. Remember, each monitoring area is a specific, targeted area or is defined by the combination of type of land and management system (see Step 5: 'Decide Where to Monitor').
6. Look at the changes in each indicator that have occurred since you first began monitoring.
7. Compare the changes that have occurred in different monitoring areas, if your monitoring objectives include any kind of comparison. Remember, if you are comparing different management systems, you should only compare monitoring areas that occur on similar types of land – that is, areas with similar soil, slope, landscape position, and vegetation.

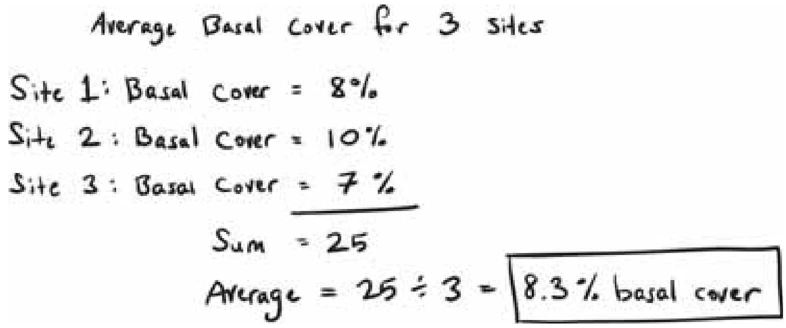
Box 9: Replicates and Averaging

Ideally, you have collected data at more than one monitoring site within each monitoring area (see Box 8: 'Replicating Monitoring Sites Within Each Monitoring Area'). We recommend that you calculate average results for these replicate sites within each monitoring area. This will ensure that your results show changes that are occurring across the whole monitoring area, not just at one monitoring site.

For example, if you are monitoring an enclosure or conservation area from which livestock have been excluded, you want to be sure that the whole enclosure or conservation area is changing. Averaging the results across all of your monitoring sites within each monitoring area will help you to determine this.

Calculate averages separately for each indicator. To calculate averages:

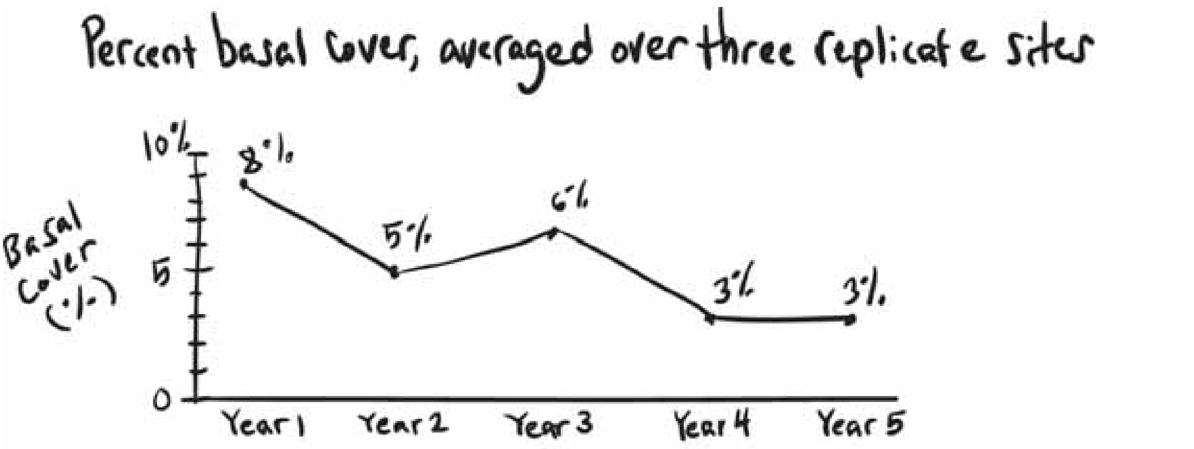
1. Add together the result values for that indicator (for example, % basal cover) from all of your monitoring sites.
2. Divide that sum by the number of monitoring sites.



Presentation

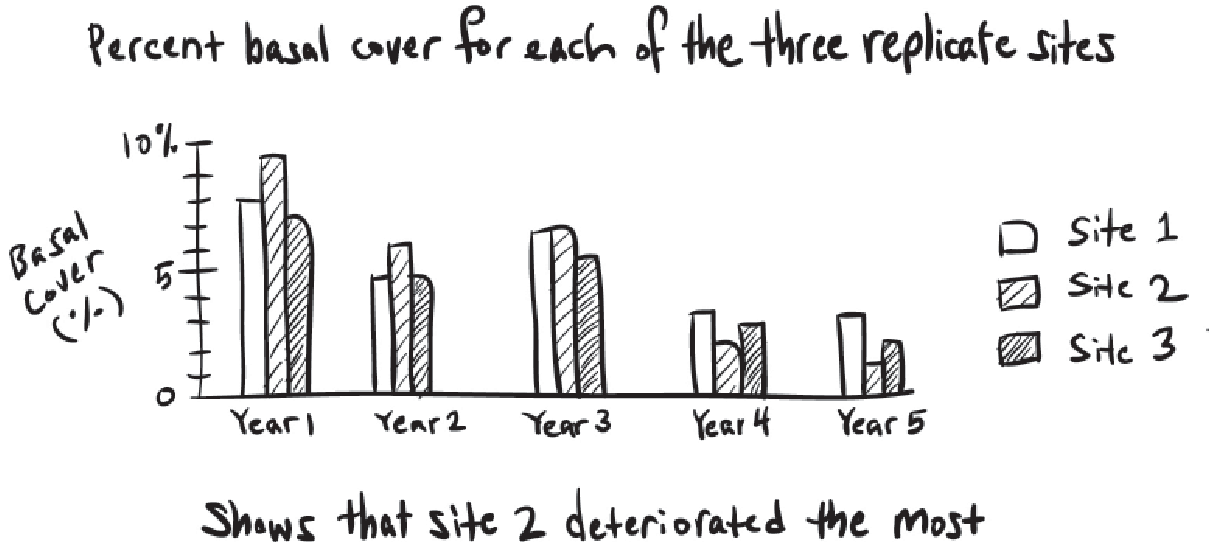
Preparing some simple charts or graphs to illustrate the results of your analysis will help you to interpret the results and share them with other land managers and stakeholders.

One of the simplest ways to do this is to chart the results for each indicator over time. For example, chart the average percent basal cover for each year of monitoring to see if this percent is increasing or decreasing.



If you are comparing two (or more) different management areas, chart the results for each management area on the same graph with a different line (see Box 7, page 35, for an example).

Another simple approach is to make bar graphs showing the changes in each monitoring site over time. This allows you to see whether some monitoring sites are changing more than others.



Interpretation

It is important that everybody involved in the monitoring process has a chance to review and interpret the results. In pastoralist communities, the interpretation should be made through a participatory process involving a diverse group of land managers and decision-makers.

1. For each indicator, consider the changes that have occurred over time and whether these changes suggest that you are – or are not – meeting your management objectives. Remember to also consider 'observational indicators' of change. (More information about how to interpret changes is given for each indicator in Section II).
2. Consider and discuss why these changes may have occurred. Use your knowledge of what may have occurred in each monitoring area (or at each individual site) as well as the 'observational indicators' of site use to help discuss and agree upon what may have caused the changes.
3. Remember that different types of land respond to management at different rates. For example, sites with deep soil at the bottom of a hill are likely to improve faster than sites with shallow soil on steep hillsides. Review the results of your assessment (Step 1b) or the 'basic site information' you collected about soil, slope, and landscape position to make a quick evaluation of each site's potential, if you did not complete Step 1b. (See also 'Interpreting Site Potential' in Section III, page 84).
4. After considering and discussing each indicator separately, consider them all together. Be sure to include the 'observational indicators' that you also collected data on. What are these indicators telling you as a whole? Is management working to achieve some management objectives but not others? Is it working in some areas, but not in others?

Documentation

After the results have been analysed, interpreted, and agreed upon, they should be documented and stored so that they can be referred to in the future. Documenting the results will facilitate the analysis and interpretation of results in future years of data collection and enable you to share your findings more widely with other stakeholders, partner organizations, or other interested parties.

Documentation of the results should include:

- How the results were analysed
- Major results
- Interpretation of results

Store these results and documentation in the storage places that were agreed upon (see Step 7: 'Document Your Specific Monitoring Plan').

Examples of How to Analyse & Interpret Results

Monitoring Two Targeted Areas:

Imagine you are worried about erosion in two areas (Monitoring Area 1 and Monitoring Area 2). Your management objective is to reduce the risk of erosion. Your monitoring objective is to see whether erosion risk is decreasing in these two areas. You have collected data from three sites in Monitoring Area 1 and three sites in Monitoring Area 2.

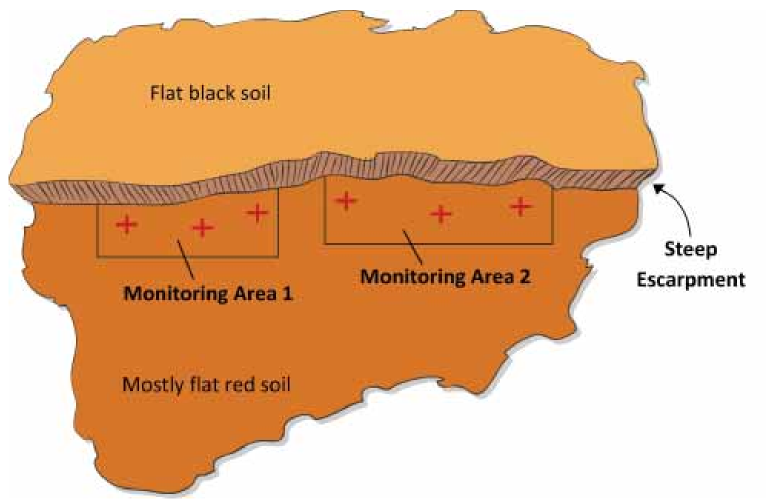
To analyse these results, you would:

- Calculate separately the indicator averages for the three sites in Monitoring Area 1 and the three sites in Monitoring Area 2.
- Then examine the changes in these averages that have occurred in each area.

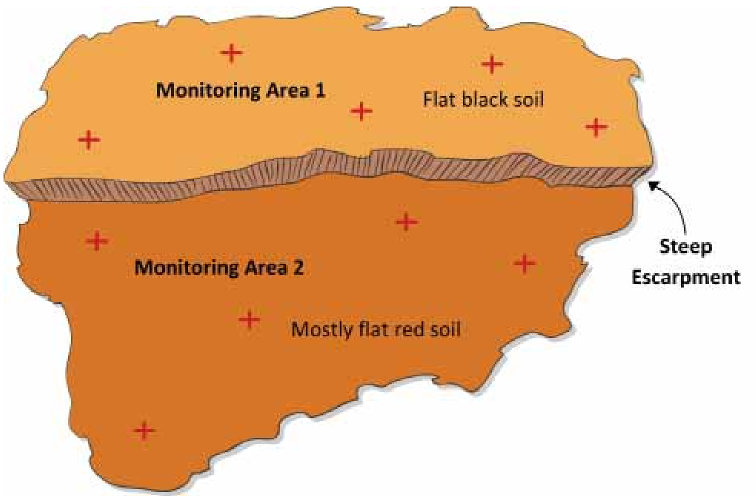
Imagine you find that:

- After two years of monitoring, Monitoring Area 1 has fewer gaps between plants and more basal cover than it did before.
- Monitoring Area 2 has more gaps between plants and less basal cover than it did before. You also observed new gullies forming in this area.

You might conclude that Monitoring Area 1 is improving and you are meeting your management objective of reducing erosion risk in this area, but that Monitoring Area 2 is getting worse and you are not meeting your management objective in this area. You might consider changing your management in Monitoring Area 2.



Monitoring Two Different Types of Land Under the Same Management System:



Imagine that there are two main soil types on your land, red and black soil. Your management objective for both is to increase forage production for livestock. Your monitoring objective is to see whether you are increasing forage production across your whole landscape. You have collected data from five sites in the red soil and five sites in the black soil.

To analyse these results, you would:

- Calculate separately the indicator averages for the five sites in the red soil and the five sites in the black soil.
- Then examine the changes in these averages that have occurred in each soil type in each monitoring area.

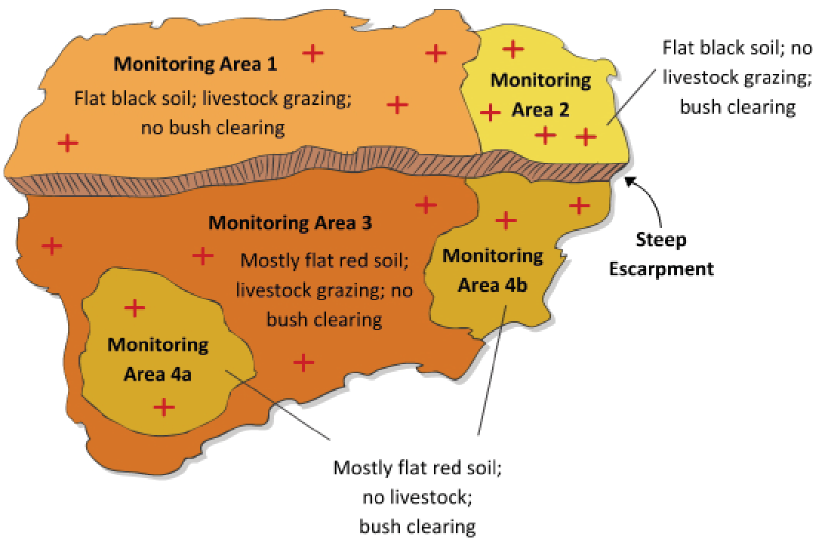
Imagine you find that:

- After two years of monitoring, the red soil has higher cover of palatable grasses and less bare ground than it did before.
- After two years of monitoring, the black soil has the same amount of cover of palatable grasses. There is no change in bare ground.

You might conclude that the red soil is improving and you are meeting your management objective of increasing forage production, but that the black soil is not changing. You might consider changing your management in the black soil, but only if you think it will help increase your forage production.

Comparing Two Different Management Systems:

Imagine you are comparing two similar areas that are being managed differently (Management Type 1 and Management Type 2) in two different types of land. Your management objective for all four monitoring areas is to reduce the risk of erosion. Your monitoring objective is to compare whether Management Type 1 or Management Type 2 is working better to reduce erosion risk. You have collected data from four sites in each of the four monitoring areas.



To analyse these results, you would:

- Calculate separately the indicator averages for the four sites in each monitoring area.
- Then compare the changes that have occurred in these averages – comparing

monitoring areas that are on the same type of land but are being managed differently.

Imagine you find that:

- In the red soil, the land under Management Type 1 has experienced a loss of basal cover, while bare ground and gaps between plants have increased. The land under Management Type 2 gained basal cover, while bare ground and gaps between plants decreased.
- In the black soil, land under Management Type 1 and Management Type 2 have both experienced an increase in basal cover and a decrease in bare ground and gaps between plants.

You would conclude that, in the red soil, Management Type 2 is working better than Management Type 1 to meet your management objective of reducing erosion. In the black soil, both Management Type 1 and Management Type 2 are working to meet your management objective.

Step 10: Learn From and Act on the Results

Collecting data is just the beginning of using monitoring as an effective tool to guide your management. The final and important step of the monitoring process is to learn from and act on the results of the monitoring. The results and interpretation of the results (from Step 9: 'Analyse and Intrepet the Results') should be presented to the wider community or group of stakeholders, and any changes in management should be agreed upon.

1. Discuss and agree upon whether management needs to be changed in any way in order to better meet your management objectives. Some questions that may help to focus the discussion include:
    a. What effects are your current management systems having on the land, relative to your management objectives?
    b. Are there some management systems that are working better than others?
    c. Are there some areas that are degrading quickly and need to be managed differently to prevent further degradation?
    d. Is the same management system having different effects in different areas?
2. Discuss possible changes to management. What are the possible options? What consequences would each of these options have, in terms of your management objectives?
3. Consider also the consequences of each of these options in terms of any other, important considerations relevant to the land. For example, how would any potential changes in management affect the lives of the people making a living from the land, in the short-term and the long-term?
4. Agree on any changes to your management or management objectives.
5. Incorporate these changes into your management plans and actions.

Section II: Monitoring Methods

The methods presented here are intended to be fast and easy to use. At the same time, they will provide quantitative data – data with numbers – so that you can compare the results of your monitoring this year with your results next year.

We present four basic methods that can all be carried out using the same datasheet and very little equipment.

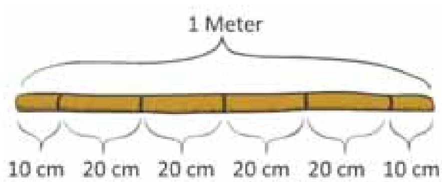
What Skills Are Needed?

Every year (year one and subsequent years): The data collector needs only to be able to count and record simple numeric information. The data analysis and calculations can be done later by somebody with more numeric skills, if the data collector is not able to do the calculations.

Year one only: In the first year of monitoring, it will be helpful for somebody who can read and write and is competent with a GPS unit to collect some background information about each site. This information only needs to be collected once but will be very useful for interpreting monitoring results.

What Equipment Will You Need?

- Datasheets
- A hard, flat board or notebook to put the datasheets on
- Pen or pencil
- Measuring sticks (easily made from any straight stick)
  - 1 or 2 sticks per data collector
  - Each stick should be 1 m long and 2-3 cm in diameter
  - Each stick should have 5 marks or notches, each one 20 cm apart (at 10, 30, 50, 70, and 90 cm)
- First time only: GPS unit, spade or other digging tool, a piece of string 5 m long, and some water



Do you need a tape measure?

No. For setting up the transects, you can pace out the 25 m instead of measuring them with a tape. If you do have access to a tape, it may be useful to practice pacing until you can reliably pace 1 m with each step.

Definitions

See the Glossary (page 91) for definitions of terms used in the instructions for the data collection.

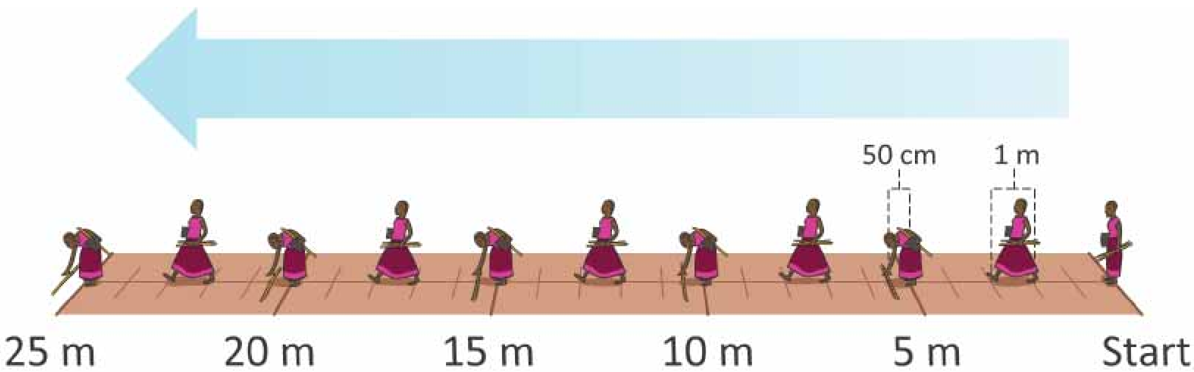
In most cases, you will only need the Background Datasheet and the Core Datasheet. These two sheets can be copied double-sided, so that the data collector only needs to carry one piece of paper to each site.

Background Datasheet

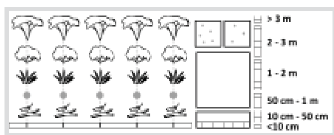
- The top half of the datasheet ('Basic Site Information') is information that only needs to be collected once, during the first year of monitoring.
- This basic site information will be useful for interpreting monitoring results.
- For each specific site, it may be useful to make photocopies of the datasheet once the basic site information *only* has been filled in. Photocopies can then be used for recording data every year, with the basic site information for that site already filled in.
- The bottom half of the datasheet ('Observational Indicators') provides space for data collectors to record some observations at each site. These data should be recorded every time data are collected.
- Observational indicators include information about site condition as well as site use. These data supplement the quantitative data collected in the Core Datasheet and will be useful for interpreting monitoring results.

Core Datasheet

- Data for all four monitoring methods can be collected using this one datasheet.
- Each corner of the datasheet focuses on one of the four methods. Each corner has a space to summarise and analyse the data.
- The datasheet is organized around a large cross (+).
- Each arm of the cross represents one 'transect.' The four transects extend in four compass directions (North, East, South, West).
- Each transect is 25 m long. You will lay down the stick and collect data every 5 m along the transect.



- For each place where you lay down the stick, you will record data in one of these boxes on the datasheet.



Basic Site Information

(Record only first time site is visited. Used for interpretation.)

Site name: ____________________

Description of where the site is located:

Description of central point location:

GPS

Datum: ____________

Northing: ____________

Easting: ____________

Vegetation Type:

	None:	Few:	Many:	Dense:
Shrubs	○	○	○	○
Trees	○	○	○	○

Common Species

Grass: ____________

Shrub: ____________

Tree: ____________

Forb/Herb: ____________

Soil Surface: 0 - 10 cm

Texture:	Colour:	Colour:
○ Sticky	○ Red	○ Light
○ Slippery	○ Grey	○ Medium
○ Sandy	○ Brown	○ Dark

Sub-Surface: 10 - 30 cm Compared to soil surface:

More:	Less:	Same:		
○	○	○	Sticky	○ Lighter
○	○	○	Slippery	○ Same as
○	○	○	Sandy	○ Darker

Sub-Surface: 30 - 50 cm Compared to 10 - 30 cm:

More:	Less:	Same:		
○	○	○	Sticky	○ Lighter
○	○	○	Slippery	○ Same as
○	○	○	Sandy	○ Darker

Soil Depth: ________ cm

Slope

Length of string: ______ m

% Slope: ____________

(% Slope = [1 / (2*length)] * 100)

Shape:
(walking down the longest slope)

Shape:
(walking across the longest slope)

Observational Indicators

(Record each time data are collected)

Season: ____________ Date: ____________

- Indicators of Change -

Signs of Erosion:

	None:	Few:	Some:	A lot:
Rills	○	○	○	○
Gullies	○	○	○	○
Litter Dams	○	○	○	○
Pedestals	○	○	○	○
Soil Deposition	○	○	○	○
Water Flow Patterns	○	○	○	○
Sheet Erosion	○	○	○	○
Other: ________	○	○	○	○

Soil Surface Hardness:

Soil surface (0 - 10 cm) in large gaps (gaps > 1 stick) is:

○ Hard ○ Soft ○ No large gaps

Soil surface (0 - 10 cm) in grassy areas is:

○ Much softer than
○ Softer than
○ The same as

the soil surface in large gaps.

- Indicators of Site Use -

Grass (not protected by shrubs/trees) has been grazed:

○ Not at all
○ Lightly
○ Moderately
○ Heavily

Species that have done most of the grazing:

____

Trees/shrubs have been browsed:

○ Not at all
○ Lightly
○ Moderately
○ Heavily

Species that have done most of the browsing:

____

Recent cutting:

○ Grass cutting
○ Tree cutting

Animals visible while at site?

○ No
○ Yes Species: ____________

Distance to water:

Temporary	Permanent	
○	○	<200 m
○	○	200 m - 1 km
○	○	1 - 3 km
○	○	>3 km

Distance to boma / settlement:

Used within the past year	Used more than a year ago	
○	○	<200 m
○	○	200 m - 1 km
○	○	1 - 3 km
○	○	>3 km

Other indicators, notes, & observations about the site:

Site name: ____________________ Date: __________

Name(s): ______________________________

Notes: ______________________________

____

Plant and Ground Cover (%)

Plant	Good	Bad	Total
Tree			
Shrub			
Grass			
Plant Base			
Litter			
Rock			
Lichen			

Note: You can write names of 'good' and 'bad' species in the 'Other indicators' section of the Background Datasheet.

Total Plant Cover	

Number of points with any kind of plant cover. Count each point only once.

Bare Ground	

Number of points with nothing circled or marked on or above the stick.

Gaps > 1m Between Plant Bases

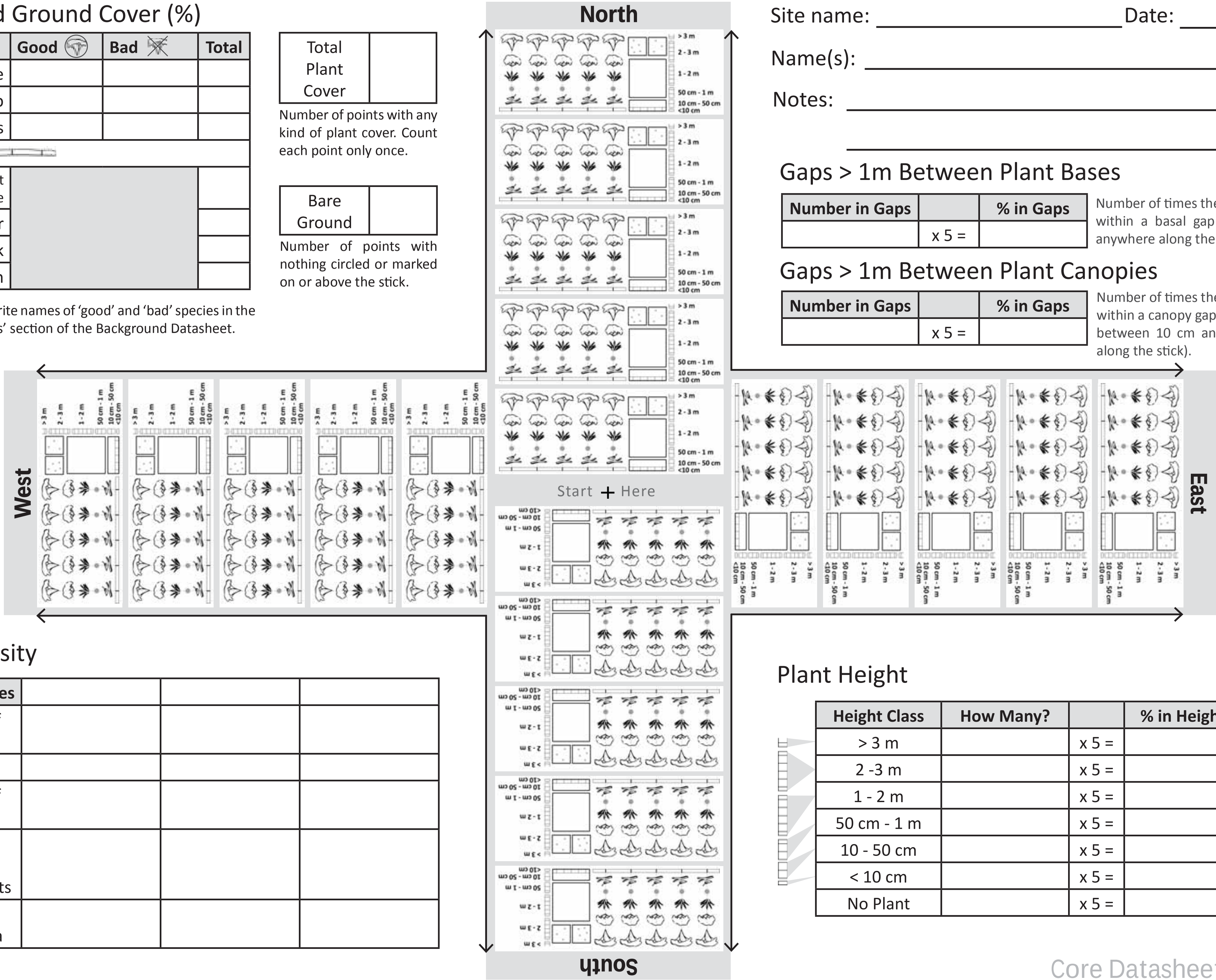
Number in Gaps		% in Gaps
	x 5 =	

Number of times the stick fell entirely within a basal gap (no plant bases anywhere along the stick).

Gaps > 1m Between Plant Canopies

Number in Gaps		% in Gaps
	x 5 =	

Number of times the stick fell entirely within a canopy gap (no plant canopy between 10 cm and 2 m anywhere along the stick).



Plant Density

Type / Species			
Number of Plants			
Plot Size			
Number of Plots			
Area = Plot size x Number plots			
Density = plants/area			

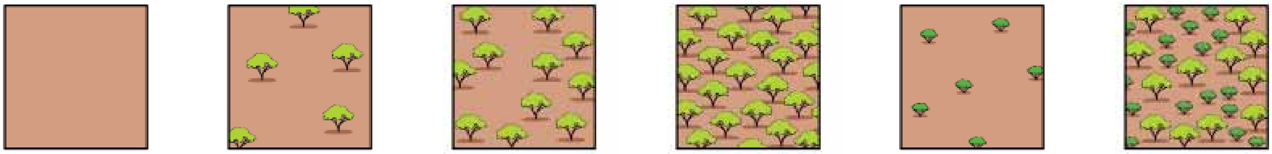
Plant Height

Height Class	How Many?		% in Height Class
> 3 m		x 5 =	
2 -3 m		x 5 =	
1 - 2 m		x 5 =	
50 cm - 1 m		x 5 =	
10 - 50 cm		x 5 =	
< 10 cm		x 5 =	
No Plant		x 5 =	

Basic Site Information

Note: These data should be collected the first time you visit the site. They do not need to be collected every year.

1. Record the name of the site.
2. Describe the location of the site – is it near any features of the landscape that will help to find the site again next time?
3. Describe the centre point of the site – are there any defining characteristics that will help to find the centre point again next time? (for example, a rock or distinctive tree). It may be useful to leave a small pile of rocks to mark the point.
4. If possible, record the GPS location of the centre point. Include the Northing, Easting, and Datum.
5. Record the vegetation type or structure at the site. For shrubs and trees, are there none, few, many, or is the area densely wooded?

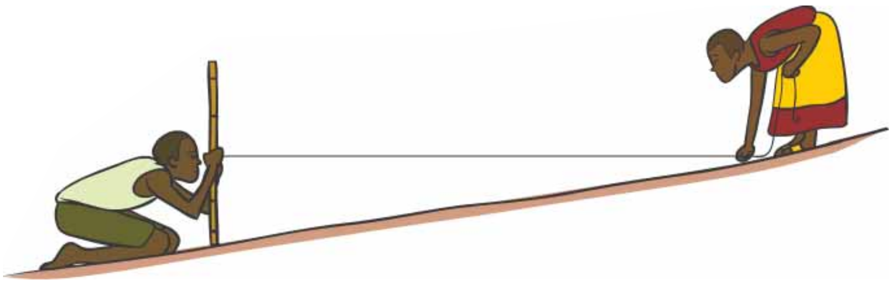


No trees; no shrubs | *Few trees; no shrubs* | *Many trees; no shrubs* | *Dense trees; no shrubs* | *No trees; few shrubs* | *Many trees; many shrubs*

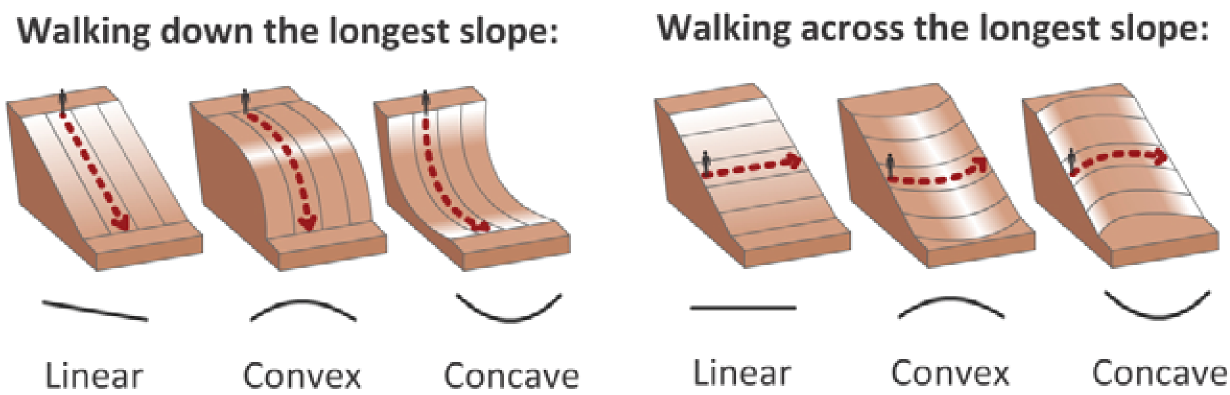
6. Record the soil depth. Dig a small trench until you hit bedrock, or look at the profile of a nearby gully. If you dig down to 50 cm and have not hit bedrock, write '> 50 cm'.
7. Wet a handful of surface soil, rolling it in the palm of your hand for several minutes to make a ball of mud. The soil should be wet enough to stick together but not glistening with water. Tick *all* the descriptions of the soil that best describe it:
    a. Is it sticky, slippery, or sandy?
    b. Is the colour red, grey, or brown?
    c. Is the colour light, medium, or dark?
8. Wet a handful of sub-surface soil (soil collected from a depth of 10-30 cm). Tick *all* the descriptions of the soil that best describe it, relative to the *surface* soil sample:
    a. Is it more or less sticky, slippery or sandy?
    b. Is the colour lighter or darker?
9. Wet a handful of deep soil (soil collected from a depth of 30-50 cm). Tick *all* the descriptions of the soil that best describe it, relative to the *sub-surface* soil sample:
    a. Is it more or less sticky, slippery or sandy?
    b. Is the colour lighter or darker?

Examples of soil samples collected from three different depths: 0-10 cm (left), 10-30 cm (middle), and 30-50 cm (right). The darker surface soil indicates that there is more organic material in the soil at the surface.

10. Determine the percent slope:
    a. Place the stick vertically on the ground. Hold one end of the 5 m piece of string at the 50 cm mark on the stick.
    b. Stand behind the stick, on the downhill side of the stick, with your eye level with the 50 cm mark on the stick. Look uphill.
    c. Find the point on the slope that is level with your eyes. Have a second person walk to this point with the other end of the string. He or she should pull the string taut, so that it makes a straight line between the top of the stick and the point on the slope that is level with your eyes. If the 5 m string is not long enough, you can pace the distance from the stick to the point on the slope that is level with your eyes and subsitute this distance for the length of the string in your calculation of percent slope (steps 10f and 10g).



    d. Have the second person mark his or her end of the string or continue holding it in the same place.
    e. Put the string on the ground and measure its length from your end to the second person's end. You can use your sticks to help measure the string.
    f. Record the length in meters (one stick = 1 m; 2. 5 sticks = 2.5 m).
    g. Percent slope = [1 / (2*length)] * 100
11. Circle the shape of the main (longest) downward slope. Imagine you are walking *down* this main slope. What is the shape of the slope as you walk down it?
12. Circle the shape of the cross-slope. Imagine you are walking *across* the main downward slope. What is the shape of this slope as you walk across it?



Interpretation of basic site information

This basic information about vegetation type, soil type, slope, and landscape position (slope shape) is very useful for two things.

First, it should be used to make sure that sites that are being compared or grouped as replicates are similar. For example, you should not compare a site with sandy soil on top of clay soil to a site that has sandy soil all the way down to 50 cm. Similarly, you should not compare a site with a steep slope to a site with a shallow slope, or a site with shallow soil to a site with deep soil. Make sure that sites are similar in terms of soil depth and texture, slope, and landscape position before you compare them or group them as replicates.

Second, this basic site information can be used to make a quick assessment of the potential of the site. Site potential information is important for interpreting the results of your monitoring and for planning future management and monitoring. See 'Interpreting Site Potential' in Section III, page 84, for a simple guide to estimating site potential based on soil characteristics and landscape position.

We suggest that you take note of important observational indicators at each site. These include **indicators of change**, as well as **indicators of site use**. This extra information can be helpful in interpreting the results of your monitoring at each site.

Note: These data should be collected every year.

Indicators of change

Erosion features:

Are there gullies, rills (small gullies), litter dams (places where litter has been pushed together by flowing water), plant pedestals, areas where soil has been deposited, water flow patterns, signs of sheet erosion, or other signs of water moving over the surface of the soil? For each one of these erosion features, are there none, few, some, or many present at the site? Tick all that apply.

Soil surface hardness:

Find several gaps between plants that are longer than the length of the stick (> 1 m). Push the soil surface with the tip of your finger. Is the soil surface in these gaps hard or soft? Or, are there no large gaps present?

Find several areas within patches of grass. Is the soil surface in these gaps much softer than, softer than, or the same as the soil surface in gaps longer than the length of the stick?

Note: If there are no patches of grass, evaluate the soil surface hardness under shrubs or trees. Note this on the datasheet.

Indicators of site use

Recent grazing intensity:

Has the grass been grazed

(a) not at all, (b) lightly, (c) moderately, or (d) heavily?

Look only at the grass that is not protected by trees, shrubs, or branches.

Are there particular species of livestock or wildlife that you know have done most of the grazing?

Recent browsing intensity:

Within the past few months, has the area been browsed:

(a) not at all, (b) lightly, (c) moderately, or (d) heavily?

Are there particular species of livestock or wildlife that have done most of the browsing?

Distance to water:

Is the nearest water source:

(a) < 200 m away, (b) 200 m - 1 km away, (c) 1-3 km away, or (d) > 3 km away?

Tick the distance in the ‘temporary’ column if the water source is temporary (seasonal) or tick the distance in the ‘permanent’ column if it is a year-round water source.

Distance to nearest boma / settlement:

Is the nearest boma or settlement that has been used within the last year:

(a) < 200 m away, (b) 200 m - 1 km away, (c) 1 - 3 km away, or (d) > 3 km away?

Is the nearest boma or settlement that was used more than a year ago:

(a) < 200 m away, (b) 200 m - 1 km away, (c) 1 - 3 km away, or (d) > 3 km away?

Other indicators, notes, and observations

This is a space to add any other observations. For example:

- Are there other indicators of change you and your community have decided to observe? Record observations here.
- Is there anything important to note about this site?
- Was this site ever a boma or settlement site? Has there been a fire at this site in the last few years? Describe any observations that support your conclusions about the site’s history.
- Is this considered a good or bad site for livestock?
- Are there wildlife species that like this site?

Interpretation of observational indicators

The **indicators of change** should be used to complement the other indicators for which you are collecting quantitative data (e.g. plant and ground cover, gaps between plants, plant height, and plant density). Generally an increase in active **erosion** and **signs of water movement** indicates that soil, nutrients, and water are being lost from the system, leading to decreased land health. Similarly, an increase in the **hardness of the soil**, both between plants and near plants, indicates that less water is able to soak into the soil for plants to use.

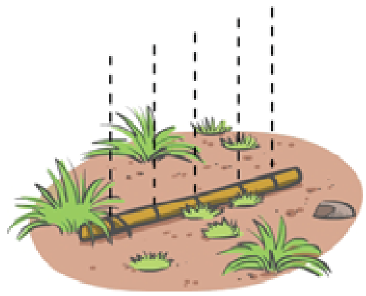
The **indicators of site use** should be used to help make sense of why the site may be changing in terms of both observational and quantitative indicators. This information may also help to understand why one particular site is behaving differently from others in the same monitoring area. For example, if a new boma or settlement is established near to the site, this might explain any decreases in plant cover at the site.

Plant and Ground Cover (cover of trees, shrubs, grasses, plant bases, litter, rock, lichen, and bare ground)

Plant and ground cover data tell you what percentage of the ground is covered by different types of plants, litter (unattached, dead plant material), lichen, rock, or not covered at all (bare ground). In some cases you may want to collect cover data separately for 'good' or 'bad' species of plants. You can write the names of these species in the 'Other indicators, notes, and observations' box on the Background Datasheet. However, you should also be sure that all data collectors are using the same list of 'good' and 'bad' species and that this list is included in the monitoring plan (see Step 7: 'Document Your Specific Monitoring Plan').

Note: This section presents only the plant and ground cover method. However, if you are also collecting other data (for example, gaps between plants, plant height, or plant density), we suggest that you collect all the data at each 'stick location' at the same time.

Collecting the data



Record only the plant and ground cover that are immediately above or below each mark on the stick

1. Walk 5 m North in a straight line from the site's centre point.
2. Put down the stick 50 cm in front of your feet. Try not to look at where you are putting it.
3. Record what type of plant and/or ground cover is present at each mark (or notch) on the stick. Choose one side of the stick (either the side closer to you or farther from you) and record only the plant and ground cover that are immediately above or below that point on the edge of the stick. Imagine that a rain drop is falling down directly onto that point: what does the raindrop hit on its way down?
4. For each point along the edge of the stick, decide what (if anything) is protecting the soil surface. Draw the appropriate symbol on that point on the stick diagram in the datasheet:
    a. If the point is on top of a **rock**, draw a small box around that point on the datasheet. 'Rock' means any piece of rock or small stone that is more than 5 mm in diameter. Even these small stones protect the soil surface from the impact of raindrops.

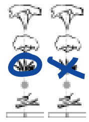
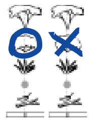
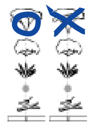
    

    b. If the point is on top of **lichen**, draw a small V over that point in the datasheet.

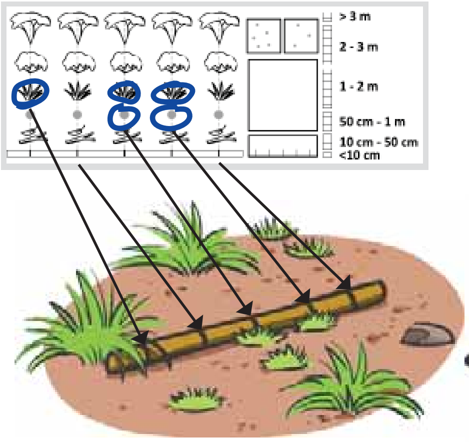
    

    c. If there is nothing permanent covering the soil surface (no rock or lichen), do not mark that point on the stick diagram in any way.
5. For each point along the edge of the stick, decide what (if any) litter or perennial plants are covering the ground at that point. This method focuses on perennial plants. If you wish to record data on annual plants, we suggest you record them as a 'key

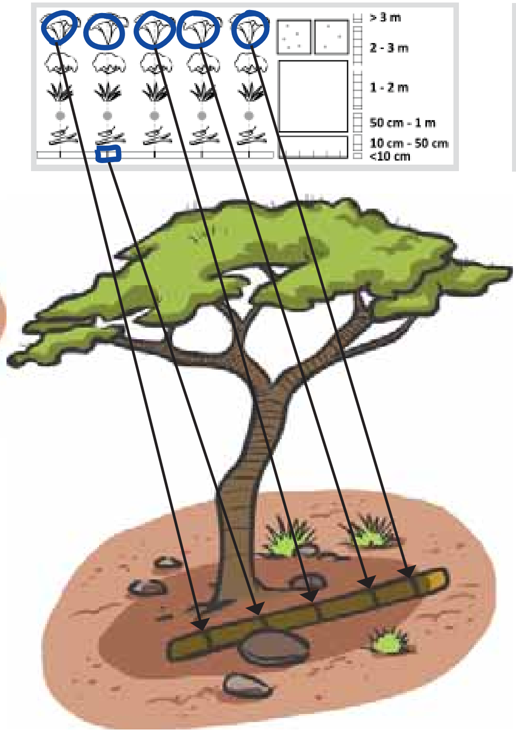
species' using a different set of symbols. See 'Collecting Cover Data for Key Species', page 64.

6. Mark the appropriate symbols above the stick diagram on the datasheet (you can circle more than one for each point). You can mark 'good' species of plants by circling the symbol, and mark 'bad' species of plants by putting an X over the symbol. Use these rules as a guide:
    a. If the point falls on top of **litter**, circle the stick and leaf symbol. Litter is unattached material, such as sticks, leaves, logs, and dung.
    
    b. If the point falls on a **plant base** (including perennial grass, forb, shrub, or tree bases), circle the small dot.
    
    c. If the point falls under or over a **perennial grass** or forb leaf or stem, mark (circle or X) the grass symbol.
    
    d. If the point falls under a **shrub** leaf or stem, mark (circle or X) the shrub symbol. Unless you are recording them separately as key species, record any succulents as shrubs.
    
    e. If the point falls under a **tree** leaf or stem, mark (circle or X) the tree symbol. Record all trees (including seedlings and saplings) as trees, not shrubs.
    
    f. Do not mark any symbol if there is no litter or plant cover at that point.
    g. Other rules:
        i. If the point falls under or over the canopy of both a 'good' and a 'bad' grass species, you can both circle and X the grass canopy symbol.
        
        ii. If the point falls on a plant base, you must also mark the canopy symbol for that type of plant. For example, if the point falls on a grass base, you must also circle or X the grass canopy symbol for that point.
        
        iii. Also mark basal and canopy cover for standing dead plants, for example standing dead trees.
7. Continue collecting cover data every 5 m until the end of the transect (laying down your stick when you stop at 5, 10, 15, 20, and 25 m from the centre point).
8. Repeat these steps for each of the three other transects (East, South, West).

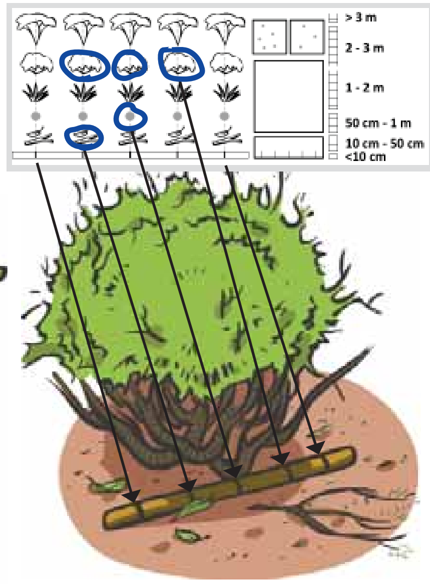
Example 1:
Grasses and bare ground



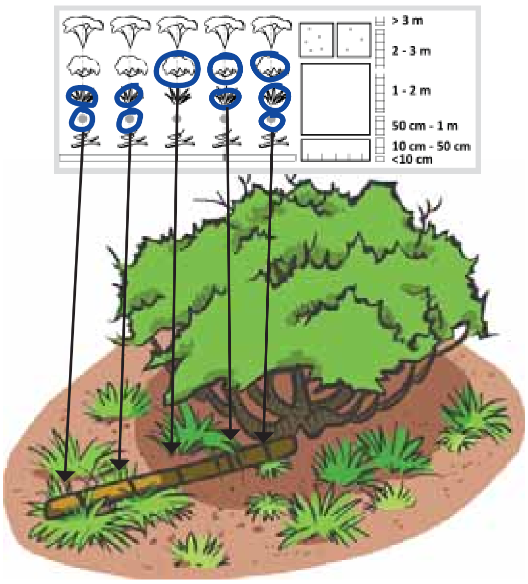
Example 2:
Tree canopy and rock



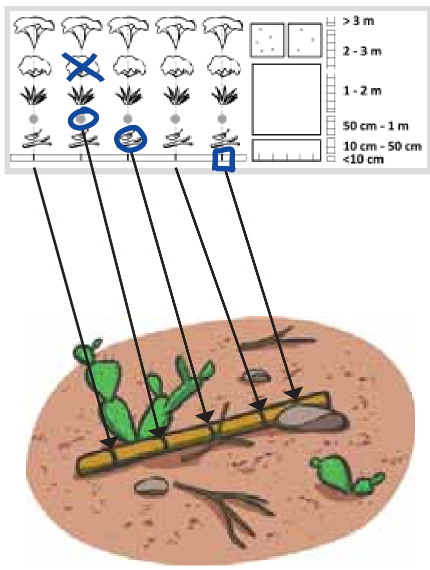
Example 3:
Shrub canopy, plant base, litter and bare ground



Example 4:
Shrub canopy, grass canopies and plant bases



Example 5:
'Bad' shrub cover, litter, rock, and bare ground



Note: If you circle the plant base symbol, also circle (or X) the canopy symbol for that type of plant. Otherwise, only circle (or X) grass, shrub, and tree canopies when a leaf, stem, or branch of that type of plant is directly over (or under) the mark on the stick.

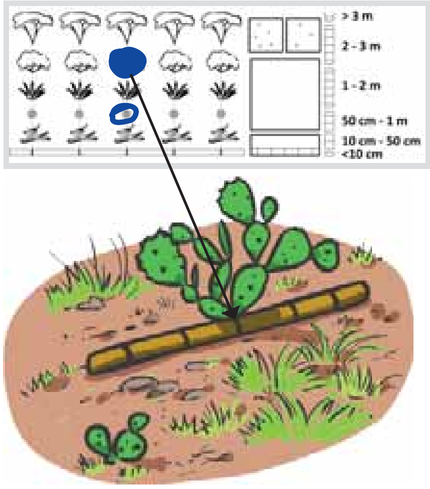
Analysing the data

1. Summarise the data in the 'Plant and Ground Cover (%)' corner of the datasheet.
2. For trees, shrubs, and grasses:
    a. Count the number of times you have circled the tree symbol. Record this under the 'Good' column. This number represents the percent cover of 'good' trees. If you did not collect separate data for 'good' and 'bad' plant species, skip to step 2c and simply record the total number of times you marked the tree symbol.
    b. Count the number of times you have put an X through the tree symbol and record this under the 'Bad' column in the datasheet. This represents the percent cover of 'bad' trees.
    c. Add together the number of trees in the 'Good' column and in the 'Bad' column. Record this number in the 'Total' column. This represents the total percent tree cover at this site.
    d. Repeat steps 2a – 2c for shrubs and grasses to get good, bad and total percent cover for shrubs and grasses.
3. For plant bases, litter, rock, and lichen:
    a. Count the number of times you marked each type of ground cover. Record these numbers under the 'Total' column. These numbers represent the percent of the ground that is protected by plant bases, litter, rock, and lichen.
4. To calculate total number of points with plant cover, count the number of points on the datasheet where you marked (with a circle or X) *any* type of plant (trees, shrub, grass or forb, or base). Count each point only once. For example, even if you have circled a grass canopy and a tree canopy, only count this point once. This is the percent total plant cover.
5. To calculate the percent bare ground, count the number of points for which you *did not* make any marks on the datasheet on or above that point on the stick. In other words, count the number of points at which a raindrop falling straight down would hit bare soil. This is the percent bare ground.

Note: You may calculate a variety of other indicators, depending on your needs. For example, you may want to know the percent of the ground that is not protected *at the soil surface* (not protected by a plant base, litter, lichen, or rock). This 'unprotected soil' can be calculated by counting the number of stick points for which you did not circle plant base, litter, lichen or rock – even if you did circle grass, shrub, or tree canopy cover. This is just one example of an additional indicator you could calculate from plant and ground cover data.

Collecting cover data for key species

There may be particular plant species that you want to monitor (for example, desirable, undesirable, or invasive trees, shrubs, grasses, or forbs). There are several options for collecting data on these species:



1. In many cases, simply marking 'good' and 'bad' species (using a circle for 'good' and an X for 'bad') will provide all the information that you need.
2. For particular, key species, you can use a different symbol to mark cover of these species on the datasheet. For example, you could draw a shaded circle over the tree symbol to indicate cover of a particular species of tree. Be sure to always use the same symbol for that species and make a note on the datasheet indicating what that symbol means.
3. If you require more detailed information on plant cover for many different species, it may be better to use a different method, such as the line-point intercept method (see 'Additional Monitoring Methods' in Section III, page 87).

Plant and ground cover basic interpretation

An increase in **basal cover** (cover of plant bases) almost always indicates reduced risk of runoff and erosion. It is also a good indicator of long-term forage availability, especially during a drought when canopy cover of perennial plants may be low. It is one of the most stable and reliable indicators of both degradation and recovery for rangelands in many parts of eastern Africa.

Conversely, an increase in **bare ground** or unprotected soil almost always indicates increased risk of runoff and erosion.

An increase in **tree or shrub cover** can be good or bad, depending on your management objectives. An increase in cover of some species of trees and shrubs – for example, species that provide good forage and shelter for livestock or wildlife – may be an indicator that you are meeting your management objectives. An increase in cover of other species – for example, species that are invasive – may be an indicator that you are not meeting your management objectives.

An increase in **perennial grass cover** usually indicates that there is more forage available for livestock and wildlife. However, perennial grass cover can change from one season to the next (depending on rainfall and grazing), so it is not always a reliable indicator of long-term change.

An increase in **litter** or **lichen** protects the soil from erosion caused by the impact of raindrops hitting the soil. It also keeps the ground cool, which is important for the soil organisms that maintain soil fertility and good soil structure. Good soil structure helps water move into the soil more quickly, reducing runoff. Litter, like perennial grass cover, varies a lot with weather and recent site use, so it is best to look at several years of litter data together.

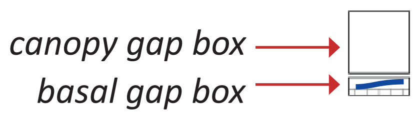
Gaps > 1 m Between Plants (Percent of Ground in Large Gaps)

The **gaps between plants** method tells you what percent of the landscape falls in large (greater than 1 m) gaps between plant bases and between plant canopies.

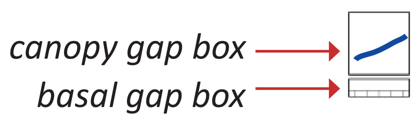
Note: This section presents only the gaps between plants method. However, if you are also collecting other data (for example, plant and ground cover, plant height, or plant density), we suggest that you collect all the data at each 'stick location' at the same time.

Collecting the data

1. Walk 5 m North from the site's centre point.
2. Put down the stick 50 cm in front of your feet. Try not to look at where you are putting it.
3. Gaps between plant bases:
    a. Shade, colour in, or mark the basal gap box on the datasheet if the stick touches any kind of plant base in any place along the stick (ignoring the marks on the stick). This indicates that the gap is broken (there is not a gap > 1 m between plant bases).

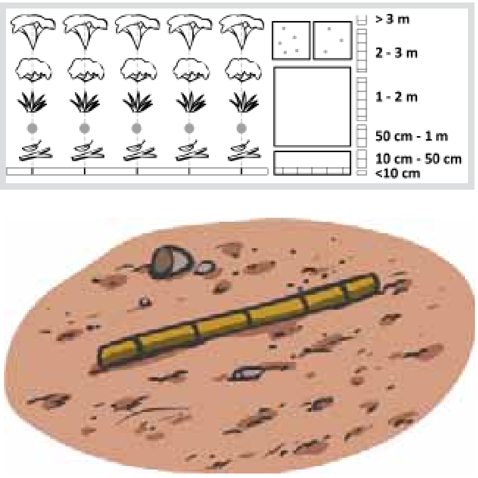
    

    b. Leave the basal gap box empty if the stick is entirely within a basal gap (the stick is not touching any plant bases). This indicates that the gap is *not* broken (there is a gap > 1 m between plant bases).
4. Gaps between plant canopies:
    a. Shade, colour in, or mark the canopy gap box if there is plant leaf or stem over any part of the stick. This indicates that there is not a gap > 1 m between plant canopies.

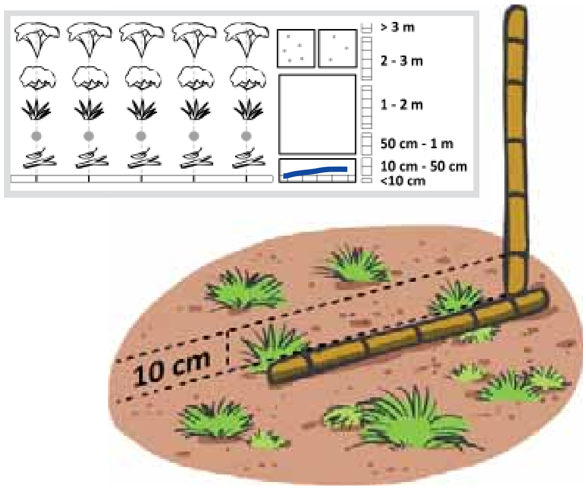
    b. Leave the canopy gap box empty if the stick is entirely within a canopy gap (there is no plant leaf or stem over the stick). This indicates that there is a gap > 1 m between plant canopies.
    c. Note: The plant leaf or stem must be between 10 cm and 2 m in height. (Canopies shorter than 10 cm or taller than 2 m are not effective at slowing wind erosion).
5. Continue collecting gap data every 5 m until the end of the transect (laying down your stick when you stop at 5, 10, 15, 20, and 25 m from the centre point).
6. Repeat these steps for each of the three other transects (East, South, West).

Example 1:
There are no plant bases or canopies along the stick, so do not mark anything. This indicates that there is a gap > 1 m between both plant bases and plant canopies.



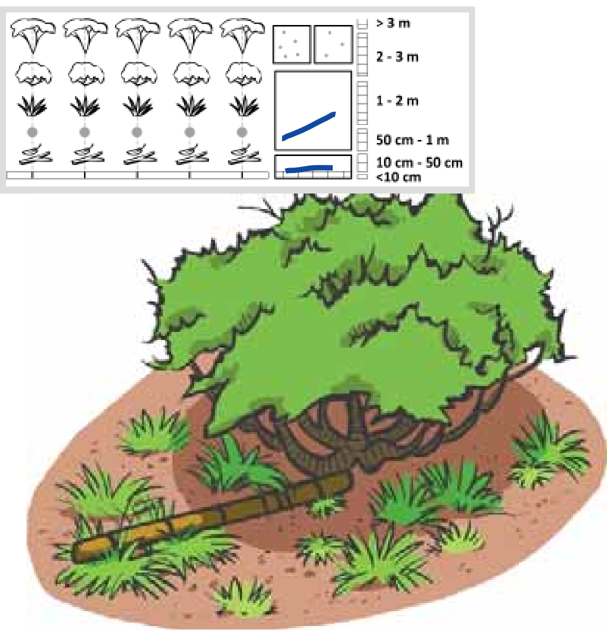
Example 2:
There are plant bases along the stick, so mark the basal gap box. This indicates that there is no gap > 1 m between plant bases.

There are no plant canopies between 10 cm and 2 m in height over the stick, so do not mark the canopy gap box. This indicates that there is a gap > 1 m between plant canopies.



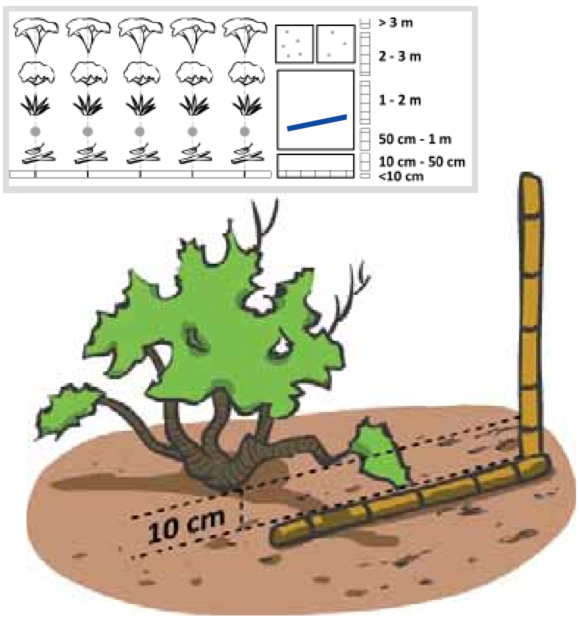
Example 3:
There are plant bases along the stick, so mark the basal gap box. This indicates that there is no gap > 1 m between plant bases.

There is a plant canopy between 10 cm and 2 m in height over the stick, so also mark the canopy gap box. This indicates that there is no gap > 1 m between plant canopies.



Example 4:
There are no plant bases along the stick, so do not mark the basal gap box. This indicates that there is a gap > 1 m between plant bases.

There is a plant canopy between 10 cm and 2 m in height over the stick, so mark the canopy gap box. This indicates that there is no gap > 1 m between plant canopies.



Analysing the data

1. Summarise the data in the 'Gaps' corner of the datasheet.
2. Count the number of basal gap boxes you did not shade or mark. (Remember, an empty box means that there was a basal gap; a shaded or marked box means that there was at least one plant base breaking up the gap). Record the number of empty basal gap boxes in the 'Gaps > 1 m Between Plant Bases' box.
3. Count the number of canopy gap boxes you did not shade or mark. (Remember, an empty box means that there was a canopy gap; a shaded or marked box means that there was at least one plant canopy breaking up the gap). Record the number in the 'Gaps > 1 m Between Plant Canopy' box.
4. Multiply each number by 5 to get the percent of the landscape that has large (> 1 m) gaps between plant bases and canopies.

Gap between plants basic interpretation

An increase in the **percent of the land with large gaps between plant bases** (at least 1 m long) indicates that there is a higher risk of runoff and erosion. Plant bases slow the flow of water, so when there are more large basal gaps there are fewer obstacles to slow the water and prevent erosion.

An increase in the **percent of the land with large gaps between plant canopies** (at least 1 m long) indicates that there is a higher risk of wind erosion. Plant canopies slow the speed of the wind, so more large canopy gaps means that wind can pass through the area more quickly and carry away more soil. Larger gaps also mean that the soil surface is hotter. At the same time, more large canopy gaps means there is less cover for small wildlife (both herbivores and predators) to hide in.

The **gaps between plants** method gives you information that you cannot get from the plant cover method alone. For example, it is possible for two sites to have the same percent cover of plant bases (or plant canopies), but for one site to have a much higher percentage of the land in large gaps between plant bases (or plant canopies) than the other (Figure 4, at right). The gaps between plants method is more important than the plant cover method for monitoring changes in the risk of erosion.

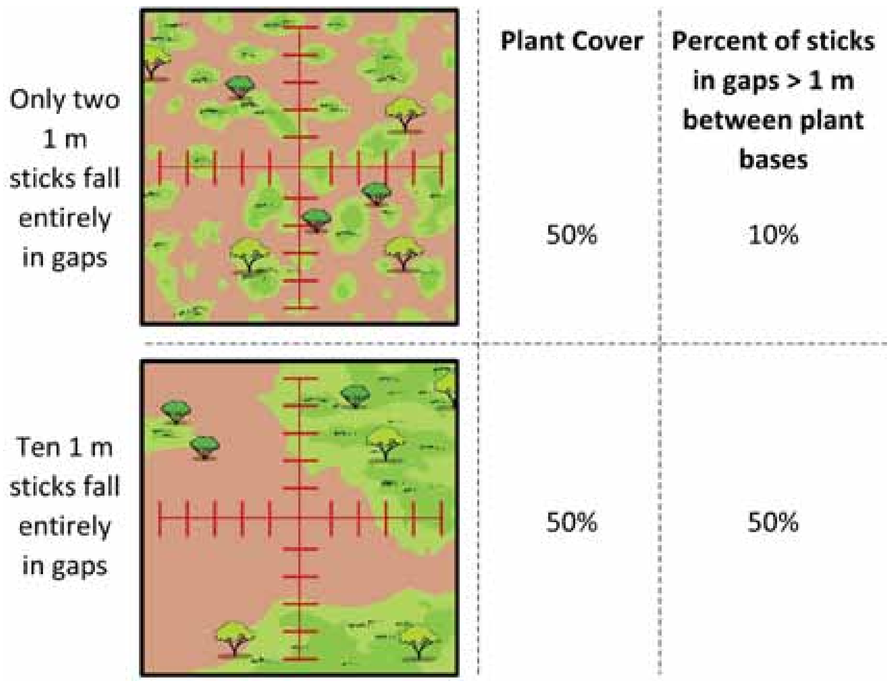


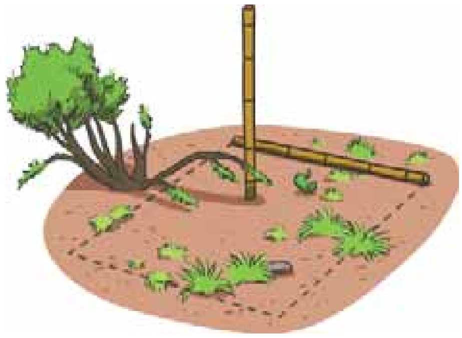
Figure 4: *Measuring gaps between plants provides information that you cannot get from only measuring plant and ground cover.*

Plant height data can be used to monitor changes in vegetation structure – or what percentage of the landscape is covered by tall versus medium versus short plants.

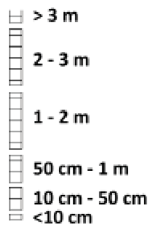
Note: This section presents only the plant height method. However, if you are also collecting other data (for example, plant and ground cover, gaps between plants, or plant density), we suggest that you collect all the data at each 'stick location' at the same time.

Collecting the data

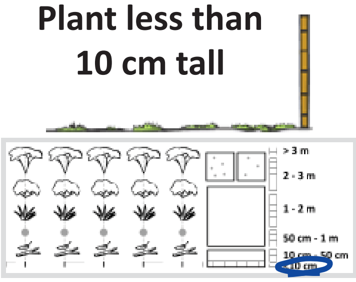
1. Walk 5 m North from the site's centre point.
2. Put down the stick 50 cm in front of your feet. Try not to look at where you are putting it.
3. Use a second stick to outline a box 1 x 1 m in front of the stick.
4. Identify the tallest plant part (branch, leaf, or stem) that is within this 1 x 1 m box. Use the second stick to estimate the height of this plant part.
5. Circle the height class of this plant part on the datasheet. Circle:
    a. '< 10 cm' if the plant part is less than 10 cm in height.
    b. '10 - 50 cm' if the plant part is between 10 and 50 cm in height.
    c. '50 cm - 1 m' if the plant part is between 50 cm and 1 m in height.
    d. '1 - 2 m' if the plant part is between 1 and 2 m in height.
    e. '2 - 3 m' if the plant part is between 2 and 3 m in height.
    f. '> 3 m' if the plant part is more than 3 m in height.
    g. Do not make any mark if there is no plant within or hanging over the 1 x 1 m box.
6. Continue collecting height data every 5 m until the end of the transect (laying down the stick when you stop at 5, 10, 15, 20, and 25 m from the centre point).
7. Repeat these steps for each of the three other transects (East, South, West).



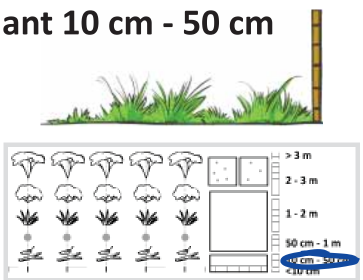
Estimate the height of the tallest plant part (branch, leaf, or stem) that is in the 1 x 1 m box, even if the plant is rooted outside the box



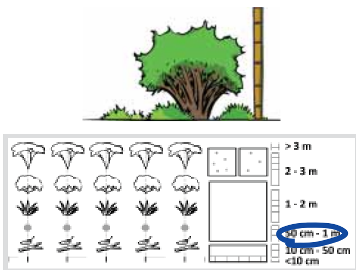
Plant less than 10 cm tall

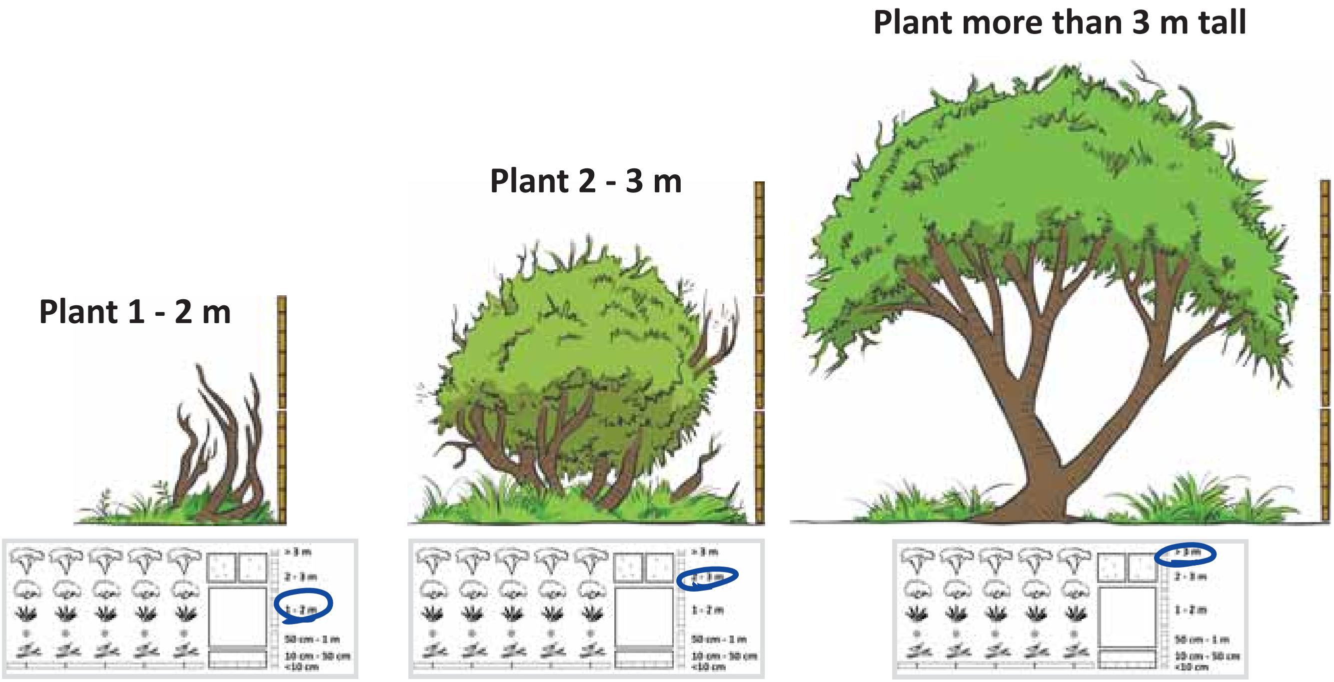


Plant 10 cm - 50 cm



Plant 50 cm - 1 m





Analysing the data

1. Summarise the data in the 'Plant Height' corner of the datasheet.
2. For each height class, count the number of times you have marked that height class on the datasheet. Record each number in the 'How Many?' column.
3. For each height class, multiply the number in the 'How Many?' column by 5. Record this number in the '% in Height Class' column.

Plant height basic interpretation

Changes in the percent of plants in each height class indicate changes in vegetation structure. Changes in vegetation structure may be related to changes in the age and health of the vegetation.

Changes in vegetation structure can also affect the quality of the habitat for wildlife. Different species prefer different vegetation structures. Changes in vegetation structure may be good or bad, depending on your management objectives and the particular species for which you are managing. If the area is changing from an area with many short plants to an area with many medium or tall plants, this may have a negative effect on wildlife that prefer shorter vegetation, such as mice, rabbits, zebras and gazelles. If the area is changing from an area with many medium-height plants to an area with many tall plants, this may have a positive effect on wildlife that prefer taller, more widely-spaced trees, such as elephants and giraffes.

Finally, changes in vegetation structure may affect wind erosion. In general, taller vegetation is better for protecting the soil from wind erosion. But very tall trees with no plants below them are not very good at protecting the soil from wind erosion. Data on canopy gaps should be combined with data on vegetation structure to decide whether there is a high or low risk of wind erosion.

Plant density data is most useful for measuring changes in the abundance of trees, shrubs, and succulents (including seedlings and adult plants) when you need a more sensitive measurement than plant cover data can provide or when plant cover is low (less than 5%). For example, plant density data may show that an undesirable species is starting to establish at a site, even if it does not have high enough cover to be captured by the plant cover data. In this example, plant density data would provide an important early warning indicator of future changes at this site.

This method can be used for all species together or for 'key' species of particular interest (for example, invading species). It can also be used to determine the density of seedlings as well as larger plants. Finally, this method can be used to measure the density of a particular species within several height classes. For example, you could measure the density of seedlings, saplings, and larger plants of an invading or undesirable species. This will give more information about how many large plants of this species you can expect there to be in the future.

Plant density data are collected by counting the number of plants that are rooted within a plot of known size. The plots should be evenly distributed throughout the monitoring site. We describe three options for measuring plant density:

Option 1: Twenty small plots (one plot at each sample point along the four transects). Each plot is 1 x 1 m, for an area of 1 m^2 per plot.

Option 2: Four 20m-long 'belt transects' (one along each of the four transects). Each 'belt' is 20 m long and 4 m wide, for a total area of 80 m^2 per plot.

Option 3: One big plot (with each end of the four transects acting as a corner). The plot is 35 x 35 m, for a total area of 1,250 m^2.

Usually smaller plots (Option 1) are better for counting plants that are small and common in the landscape. Larger plots (Option 2) are better for counting plants that are medium-sized (most shrubs and small trees) and are relatively common in the landscape. Very large plots (Option 3) are best for counting plants that are large (big trees) or uncommon in the landscape (for example, seedlings of a species that is just starting to invade the area).

We have suggested plot sizes for each of these three options. However, you may choose to adjust the plot size or belt transect width to suit your situation.

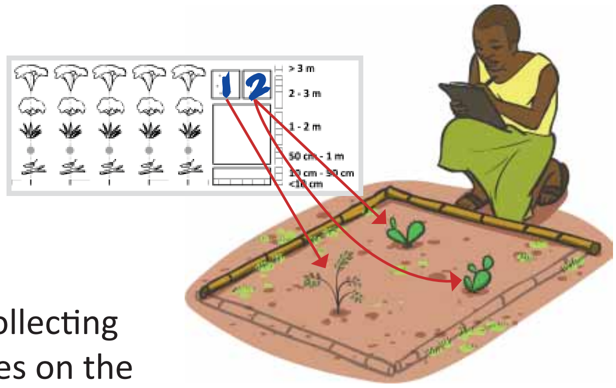
Whichever option you choose, *use the same size and number of plots at every site you monitor.*

Collecting the data

1. Record the type and/or species of the plants you are counting in the 'Plant Density' corner of the datasheet. You can collect data at the same time for more than one type or species (two at a time using Option 1 and three at a time using Options 2 and 3). For example, you could collect data for all shrubs and all trees, or for three different species of trees, at the same time.

Option 1: Twenty 1 m² plots

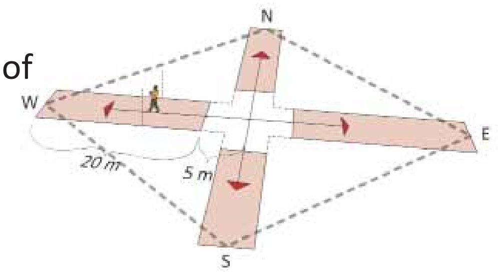
2. Walk 5 m North from the site's centre point.
3. Put down the stick 50 cm in front of your feet. Try not to look at where you are putting it.



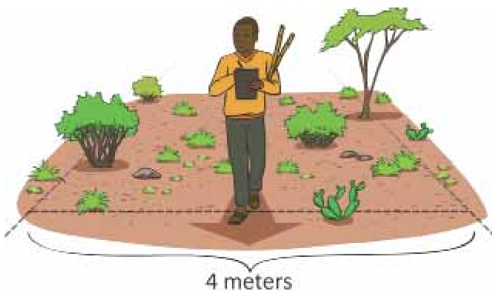
4. Use a second stick to outline a square box (1 x 1 m) in front of the stick on the ground.
5. Count the number of plants that are rooted inside the plot (the base of the stem is inside the plot).
6. Record this number (or numbers, if you are collecting data for two species) in the small density boxes on the datasheet.
7. Continue collecting plant density data in 1 x 1 m plots every 5 m until the end of the transect (laying down plots when you stop at 5, 10, 15, 20, and 25 m from the centre point).
8. Repeat these steps for each of the three other transects (East, South, West).
9. Add the numbers in all of the small boxes together to get the total number of plants of each type or species that you counted. Record this total number (or numbers) in the 'Number of Plants' row of the datasheet.
10. Record the size and number of plots in the 'Plot Size' and 'Number of Plots' rows.

Option 2: Four 20 m-long belt transects (Four 80 m² plots)

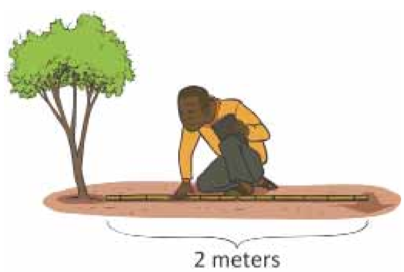
1. Walk 5 m North from the site's centre point.



2. Walk slowly in a straight line, counting the number of plants with the base of the stem (or trunk) rooted within 2 m on either side of the line. Use the sticks to measure 2 m from the line if you are not sure whether the plant is inside the belt or not.



3. For plants on the edge of the plot: count them if more than half of their stem or trunk is within (inside of) 2 m of the line; do not count them if more than half of their stem or trunk is more than 2 m from the line.
4. For each plant that you count, record a tally mark in the 'Number of Plants' row in the 'Plant Density' corner of the datasheet.

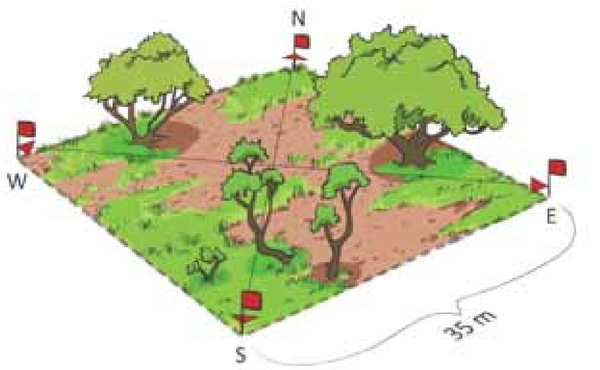


5. Continue walking and counting until you have reached the end of the transect (25 m from the centre point).
6. Repeat these steps for each of the three remaining other transects (East, South, West).

7. Count the number of tally marks you have made for each type of plant and write this total in the 'Number of Plants' row of the datasheet.
8. Record the size and number of plots in the 'Plot Size' and 'Number of Plots' rows.

Option 3: One 1,250 m² plot

1. Mark the end of each of the four transects that you used for plant cover, plant height, and gaps between plants. Each marked point should be 25 m from the site's centre point. These are the corners of the single plot. Draw an imaginary line between each of the four transect ends to form one big square plot.



2. Count the number of plants whose base of the stem (or trunk) is rooted inside the plot.
3. For plants on the edge of the plot: count them if more than half of their stem or trunk is inside the plot; do not count them if more than half of their stem or trunk is outside the plot.
4. Record the total number of trees and/or shrubs in the 'Number of Plants' row in the 'Tree Density' corner of the datasheet.
5. Record the size and number of plots in the 'Plot Size' and 'Number of Plots' rows.

Analysing the data

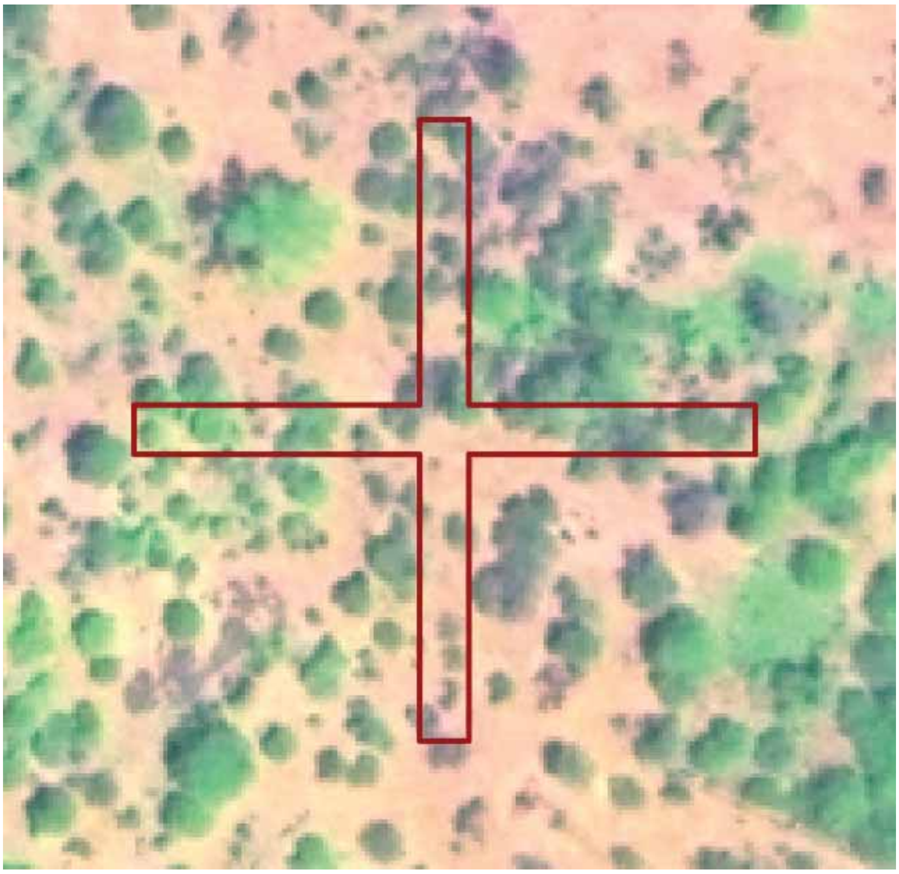
1. Calculate the area you sampled: area sampled = plot size x number of plots.
2. Calculate plant density: plant density = total number of plants / area sampled.

Plant density basic interpretation

An increase in **plant density** may be good or bad, depending on your management objectives. An increase in the density of some species, for example trees and shrubs that provide good forage for livestock, may be an indicator that you are meeting your management objectives. An increase in the density of other species, for example species that are invading, compete with grasses, or tend to colonise bare ground once the grasses have died out, may be an indicator that you are not meeting your management objectives. An increase in tree density may also indicate that the habitat structure is changing in the land. Use changes in tree density combined with changes in plant height to determine whether habitat structure is changing towards or away from your management objectives.

An increase in **seedling density** is a good early-warning indicator of future changes in the amount of cover of this plant species in the landscape. As with any other plants, an increase in seedling density may be good or bad, depending on your management objectives.

The data in these example datasheets (both the Background Datasheet and Core Datasheet) were collected from the site pictured in the satellite image below. Notice that the South transect has the lowest amount of plant cover, while the East and West transects have the highest cover. Even though plant cover was relatively high at this site (45% tree cover and 52% total plant cover), basal cover was quite low (6%). With low basal cover, there is little to slow the flow of water on this hillside. Notice that many signs of erosion and a hard soil surface were noted in the 'Observational Indicators' section.



Basic Site Information

(Record only first time site is visited. Used for interpretation.)

Site name: Jackal Kopje

Description of where the site is located:

West of exclosure fence

Description of central point location:

Bare patch by large A. mellifera 50 m west of fence

GPS

Datum: WGS 84 (UTM)

Northing: 0032879

Easting: 0264317

Vegetation Type:

	None:	Few:	Many:	Dense:
Shrubs	○	●	○	○
Trees	○	○	●	○

Common Species

Grass: Cynodon; Eragrostis

Shrub: Rhus; Croton

Tree: A. mellifera; A. tortilis

Forb/Herb: Ocimum; Plectranthus

Soil Surface: 0 - 10 cm

Texture:	Colour:	Colour:
○ Sticky	● Red	○ Light
● Slippery	○ Grey	● Medium
● Sandy	● Brown	○ Dark

Sub-Surface: 10 - 30 cm

Compared to soil surface:

More:	Less:	Same:		
○	○	○	Sticky	● Lighter
○	●	○	Slippery	○ Same as
●	○	○	Sandy	○ Darker

Sub-Surface: 30 - 50 cm

Compared to 10 - 30 cm:

More:	Less:	Same:		
○	○	○	Sticky	● Lighter
○	●	○	Slippery	○ Same as
●	○	○	Sandy	○ Darker

Soil Depth: >50 cm

Slope

Length of string: 6 m

% Slope: 8.3%

(% Slope = [1 / (2*length)] * 100)

Shape:
(walking down the longest slope)

Shape:
(walking across the longest slope)

Observational Indicators

(Record each time data are collected)

Season: Dry

Date: March 3, 2010

- Indicators of Change -

Signs of Erosion:

	None:	Few:	Some:	A lot:
Rills	○	○	●	○
Gullies	●	○	○	○
Litter Dams	○	○	●	○
Pedestals	○	●	○	○
Soil Deposition	○	●	○	○
Water Flow Patterns	○	○	○	●
Sheet Erosion	○	○	○	●
Other: ________	○	○	○	○

Soil Surface Hardness:

Soil surface (0 - 10 cm) in large gaps (gaps > 1 stick) is:

● Hard ○ Soft ○ No large gaps

Soil surface (0 - 10 cm) in grassy areas is:

○ Much softer than
● Softer than
○ The same as

the soil surface in large gaps.

- Indicators of Site Use -

Grass (not protected by shrubs/trees) has been grazed:

○ Not at all
○ Lightly
● Moderately
○ Heavily

Species that have done most of the grazing: unknown wildlife

Trees/shrubs have been browsed:

○ Not at all
○ Lightly
● Moderately
○ Heavily

Species that have done most of the browsing: elephants

Recent cutting:

○ Grass cutting
○ Tree cutting

Animals visible while at site?

● No
○ Yes Species: ________

Distance to water:

Temporary	Permanent	
○	○	<200 m
○	○	200 m - 1 km
○	●	1 - 3 km
○	○	>3 km

Distance to boma / settlement:

Used within the past year	Used more than a year ago	
○	○	<200 m
○	○	200 m - 1 km
●	●	1 - 3 km
○	○	>3 km

Other indicators, notes, & observations about the site:

Bedrock exposed in some places

Site name: Jackal Kopje Date: March 3, 2010

Name(s): Franklin, Francis, Jackson, Wilson

Notes:

Plant and Ground Cover (%)

Plant	Good	Bad	Total
Tree			45
Shrub			1
Grass			15
Plant Base			6
Litter			11
Rock			0
Lichen			34

Note: You can write names of 'good' and 'bad' species in the 'Other indicators' section of the Background Datasheet.

Total Plant Cover	52

Number of points with any kind of plant cover. Count each point only once.

Bare Ground	25

Number of points with nothing circled or marked on or above the stick.

Gaps > 1m Between Plant Bases

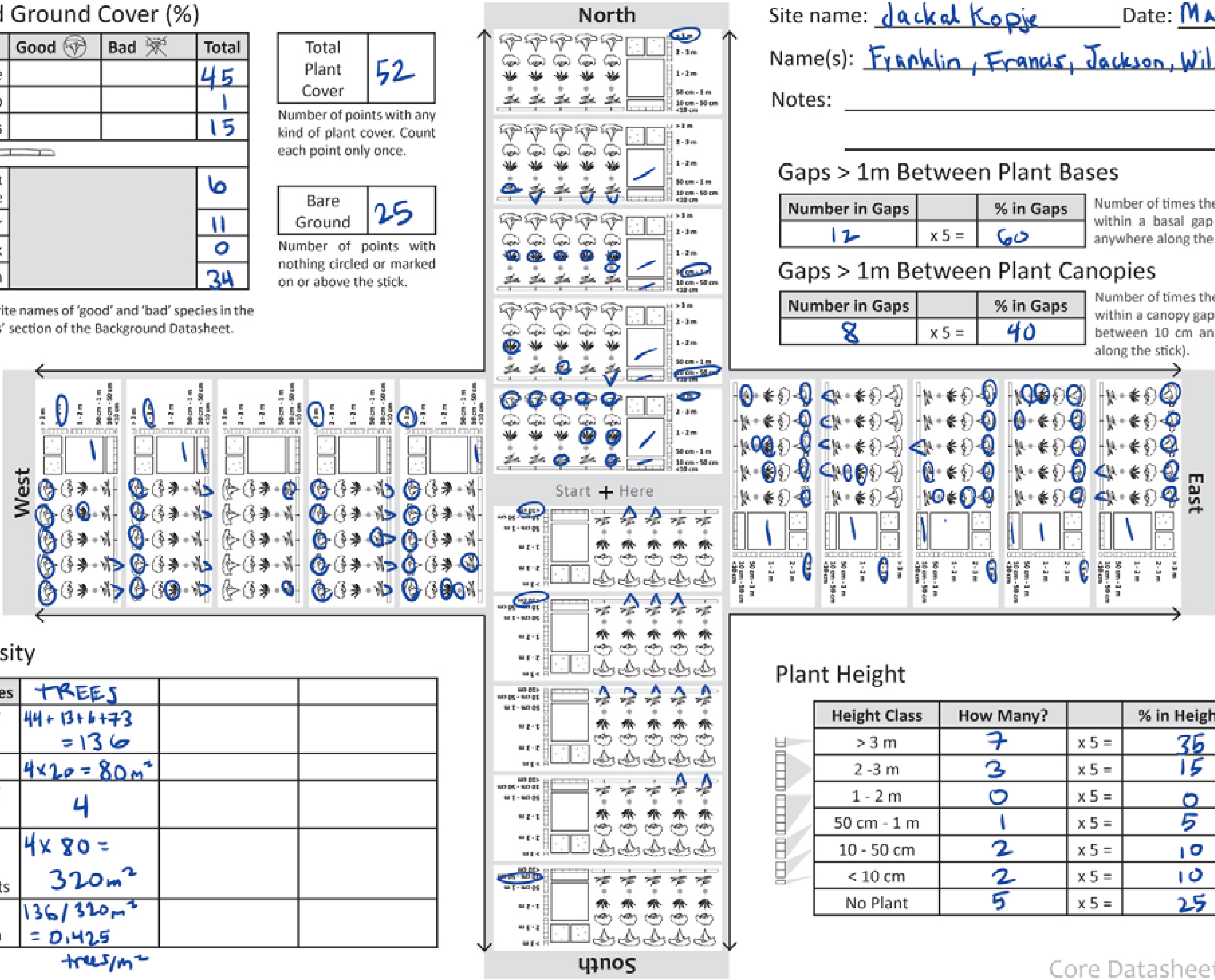
Number in Gaps		% in Gaps
12	x 5 =	60

Number of times the stick fell entirely within a basal gap (no plant bases anywhere along the stick).

Gaps > 1m Between Plant Canopies

Number in Gaps		% in Gaps
8	x 5 =	40

Number of times the stick fell entirely within a canopy gap (no plant canopy between 10 cm and 2 m anywhere along the stick).



Plant Density

Type / Species	TREES		
Number of Plants	44+13+6+73 = 136		
Plot Size	4x20 = 80m²		
Number of Plots	4		
Area = Plot size x Number plots	4x80 = 320m²		
Density = plants/area	136/320m² = 0,425 trees/m²		

Plant Height

Height Class	How Many?		% in Height Class
> 3 m	7	x 5 =	35
2 - 3 m	3	x 5 =	15
1 - 2 m	0	x 5 =	0
50 cm - 1 m	1	x 5 =	5
10 - 50 cm	2	x 5 =	10
< 10 cm	2	x 5 =	10
No Plant	5	x 5 =	25

Section III: Additional Resources

People and animals need plants, and plants need soil and water.

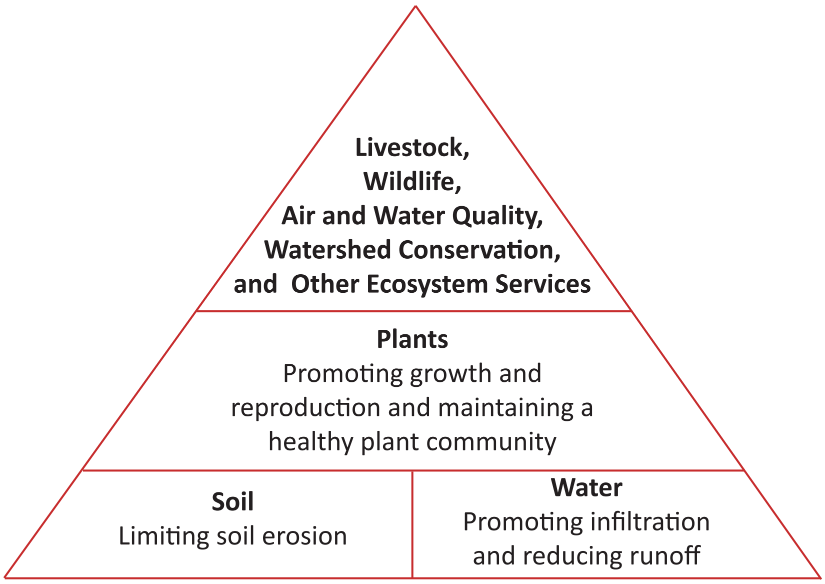
In this guide, we focus on monitoring indicators that tell us how well rangelands are doing three basic things:

(1) Sustaining the soil

(2) Sustaining the water available to plants

(3) Sustaining the plant community

These three processes form the foundation for all of the other goods and services one might want from the land – such as livestock production, good habitat for wildlife, clean air and water, and other ecosystem services. Each of these three 'blocks' of the foundation also depend on the others; if one block begins to degrade, the other two will soon follow. Healthy rangelands are sustaining all three of these processes.



Sustaining the soil (soil and site stability)

In order for plants to continue to grow, we must retain the soil and the nutrients in that soil. Once soil has eroded away, it is effectively lost; it usually takes a very long time for new soil to replace lost soil, especially if the new soil must be formed from bedrock.

Retaining soil – and the nutrients in it – depends on two things: how resistant the soil surface is to wind and water erosion, and how well protected the soil surface is from wind, raindrops, and rapidly flowing water.

Soil resistance to erosion

The soil surface loses its ability to resist erosion when it does not have enough *organic matter* in it. Organic matter is decomposed plant and animal material – such as decomposed roots, litter, or dung. Small organisms that live in the soil help to decompose large pieces of organic matter into smaller materials. These materials, as well as clay particles, act like glue – holding the soil particles together. When there is enough of this 'glue' holding the surface soil together, water and wind cannot carry the soil away. When there is not enough organic matter, the soil surface is susceptible to erosion.

> Indicators:
> *cover of litter and lichen; soil stability test*

Organic matter, especially highly decomposed material, is also essential for sustaining plant growth. Plants get many of their nutrients from decomposed organic matter. Thus, without enough organic matter, the soil loses its fertility, resulting in smaller, less productive plants.

In order to keep enough organic matter in the soil, there must be a steady input of new organic matter. Most new organic matter comes from plant roots, with some also coming from litter (dead plant material, such as leaves and stems). When plants are overgrazed or overbrowsed, they have less energy to produce roots and there are fewer dead leaves to fall to the ground. When there are large areas of bare soil without plants, there are also fewer roots and no litter to introduce new organic matter into the soil. Litter also helps to keep the soil surface cool, providing a good environment for the fungi and other soil organisms that help break down large pieces of organic matter into smaller pieces.

Where there are large gaps between plants, special soil organisms such as lichens and cyanobacteria can colonise the soil surface. These organisms – which make the surface of the soil look black or green – produce some organic matter, helping to hold the soil together. In many degraded areas, these 'biological crusts' are the only thing preventing the soil from eroding.

Protecting the soil from erosion

Plant canopies, litter, lichen, and rocks protect the surface of the soil from wind erosion and the impact of raindrops. When the soil surface is not protected, raindrops can break the soil into small particles, especially when there is not much organic matter ('glue') in the soil. These small particles can then be eroded by water. They can also form a hard, 'physical crust' that has a low infiltration rate (see below). Wind erosion can also carry the soil away if the soil surface is not protected. Wind erosion is more likely to occur where plant and ground cover is low and where plant canopies are far apart from each other.

Plant bases and rocks also slow the flow of water over the soil surface. When water is moving more slowly, it has more chance to soak into the soil and less chance to erode the soil away. Erosion by water is more likely to occur where plant basal cover is low and where plant bases are far apart from each other (see Figure 4 on page 67). In areas with large gaps between plant bases, flowing water can also carry litter away.

An area with fifty percent (or more) plant cover can effectively protect the soil surface from wind and water erosion – if the plants are evenly distributed with small gaps between them. Where plant cover is concentrated in large patches (leaving large gaps), wind and water can easily carry soil away.

> Indicators:
> *total plant cover; cover of plant bases, litter, lichen, and rock; gaps between plant bases; gaps between plant canopies*

Sustaining the water available to plants (hydrologic function)

In order for plants to grow, they must be able to use most of the rain that falls from the sky. For this to happen, the rain water must be able to soak into the soil and not evaporate away. More water can get into the soil when there is a high *infiltration rate* (the rate at which water soaks in) and when the water has plenty of time to soak in.

Infiltration rate

Healthy soils are full of 'pores' – or small pockets of space between the soil particles. Water soaks into the soil through larger pores and get stored in smaller pores. When there is more organic matter in the soil, there are more pores. Soil organisms – such as insects and burrowing animals, as well as plant roots – also help to create larger pores. In areas with plenty of organic matter, plant cover, and soil organisms, water can soak into the soil quickly. Where plant cover and organic matter are low, however, there are fewer pores and water takes a long time to soak into the soil.

> Indicators:
> *soil surface hardness; cover of plants and litter; soil stability test*

When soil is compacted (for example, around water holes that animals visit every day) the large pores get compressed. With fewer large pores, water takes longer to soak into the soil. Disturbing or breaking up the soil surface can increase the infiltration rate during the first storm after the disturbance. However, the only way to increase infiltration rate in the long-term is to increase the amount of organic matter in the soil.

Time for water to soak in

In order for water to soak into the soil, it must be moving slowly over the soil surface. In areas with more plant bases and rocks, water flows more slowly over the soil surface and has more time to soak in. In areas with few plant bases and large gaps between plant bases, water can flow quickly over the surface of the soil without soaking in. Clumps of litter and small depressions in the soil can also slow the flow of water, allowing it to soak in.

> Indicators:
> *cover of plant bases, rock, litter; gaps between plant bases*

Sustaining the plant community (biotic integrity)

As we have seen, sustaining a healthy plant community depends on sustaining the soil and sustaining the water available to plants in the soil. At the same time, sustaining a healthy plant community also *contributes* to sustaining the soil and the water and nutrients in that soil.

For a plant community to be healthy, individual plants must be able to grow and reproduce. For many management objectives, a healthy plant community also means that most of the plants are perennial and palatable, with few or no invasive plants.

Plant growth and reproduction

In order to sustain plant cover, particularly cover of important forage species, plants must have a chance to grow and reproduce. Plants require nutrients, water, and light to grow. The availability of nutrients and water depends on how well the soil – and the availability of water and nutrients in the soil – are sustained (see above). In arid and semi-arid lands, light is generally abundant. However, individual grass plants that have not been grazed at all can have lots of dead or decadent leaves; these older leaves can shade new leaves so much that the new leaves do not grow well. Often, maintaining a high cover of relatively young grass leaves for as much of the time as possible – through some level of grazing – leads to higher overall grass production. When new leaves and stems are constantly being grazed (or browsed) as soon as they are produced, the plants lose their ability to grow. As a result, their root systems shrink and the plants are no longer able to take up as many nutrients or as much water from the soil.

> Indicators:
>
> *cover of plant canopies and bases; plant density; recent grazing and browsing activity*

Plants that are healthy and growing well tend to produce more seeds than less healthy plants. Plants that are grazed or browsed as soon as they produce new leaves often do not have a chance to produce seeds. Once the seeds have been produced, they need the right conditions to sprout and grow into seedlings. Areas with some plant cover or litter often provide good sites for seedlings to sprout. Areas that have large patches of bare ground and poor infiltration do not provide good sites for seedlings. Disturbances, such as animals breaking up bare ground with their feet, can temporarily create small water catchments where seedlings can establish. In the long term, improving infiltration and reducing runoff are the best ways to create good sites for seedlings to establish. Some plants reproduce by sending out new shoots rather than producing seeds. For these plants, disturbances can also temporarily create opportunities for new shoots to establish; in the long run, however, the heath of these plants also depends on how well the soil and the water in the soil are sustained.

Species composition

Sustaining a healthy plant community means sustaining growth and reproduction for a variety of plant species. The ‘right’ group and number of species varies from location to location. In most parts of eastern Africa, a healthy plant community is made up of:

- Mostly perennial plants, with few annual plants
- Several species within each type of plant (e.g., more than one species of perennial grass)
- Few or no invasive or non-native plants

> Indicators:
>
> *plant cover; plant density; plant cover for ‘good’ and ‘bad’ species and/or key species*

Areas that have lost much of their plant diversity may not be able to resist or recover from the effects of large disturbances, such as droughts. Areas that have become dominated by a few, undesirable plant species also tend to have lower forage productivity than they used to.

All three foundation blocks work together

As we have seen, sustaining the soil, sustaining the water available to plants, and sustaining the plant community itself all depend on each other. That is why we recommend monitoring indicators of all three of these fundamental processes. By monitoring all three processes, you are more likely to catch – and reverse – early signs that the foundation is beginning to crumble – or see early signs that the foundation is beginning to recover. For example, if your monitoring shows that a site is not sustaining its soil very well, this suggests future problems with sustaining plant growth and productivity, even if the plant community appears healthy right now.

Plants, water, and soil are the basic foundation blocks on which livestock, wildlife, and people depend. By monitoring changes in these foundation blocks, you are taking a critical step towards keeping the foundation – and all the things that depend on it – intact.

Healthy Land

Small gaps between plants

Many plants and roots

Litter on soil surface

Good soil structure

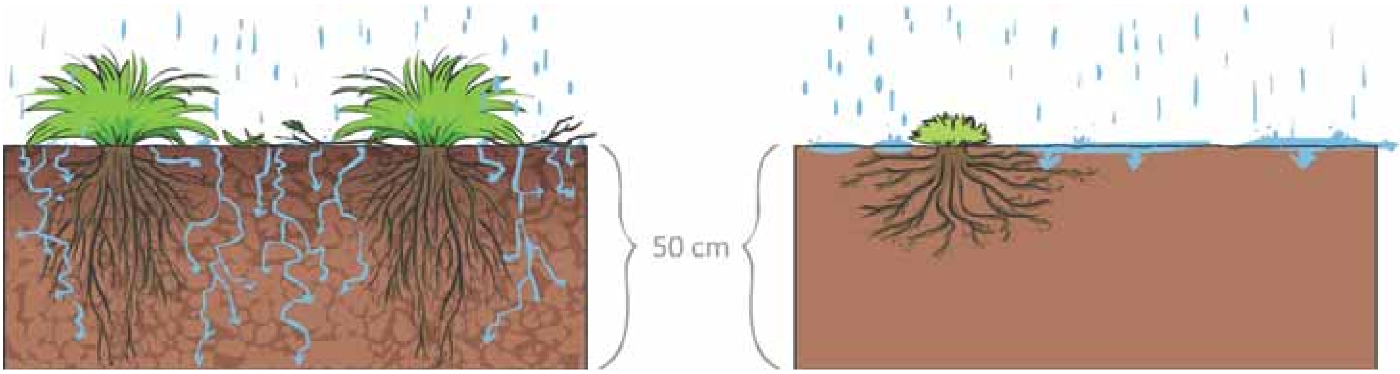
Unhealthy Land

Large gaps between plants

Few plants and roots

No litter

Poor soil structure



This landscape is functioning well because:

1. There is plenty of organic matter in the soil, so the soil is resistant to erosion
2. There are many pores, so infiltration is fast
3. The gaps between plants are small, so water flows slowly and there is time for it to soak into the soil
4. Plant and ground cover is high, so the soil surface is protected from the impact of raindrops

This landscape is not functioning well because:

1. There is little organic matter, so resistance to erosion is low
2. There are few pores, so infiltration is slow
3. There are large gaps between plants, so water flows away quickly instead of soaking into the soil
4. Plant and ground cover is low, so the soil surface is not protected from the impact of raindrops

Different sites have different potentials, depending on the climate, soil, slope, and the site's position in the landscape. Below, we give an introduction to how soil, slope, and landscape position affect site potential. Understanding differences in potential will help to:

- Guide management decisions about the land
- Decide where and what to monitor, and
- Interpret the results of your monitoring – and any changes in the land – at different sites

Soil

The fertility, depth, and texture of the soil all affect site potential. A more fertile soil will have higher potential than a less fertile soil. A deeper soil will hold more water, and therefore have higher potential, than a more shallow soil.

Soil texture influences site potential in a somewhat more complex way. Figure 5 shows how soil texture at the surface (0 - 10 cm) and below the surface (10 - 50 cm) can combine to influence site potential. Water will soak into soil that is sandy at the surface, but will run off of soil that has a lot of clay at the surface. Soil that is sandy below the surface, however, will not hold much water (Figure 5a). Soil that has a lot of clay below the surface will act like a sponge and hold more water (Figure 5b). Soil that has sand at the surface and clay below the surface (Figure 5c) will have the most water available for plants because the water soaks into the sandy surface quickly and is held by the clay below the surface. This type of soil will have the highest potential for plant production.

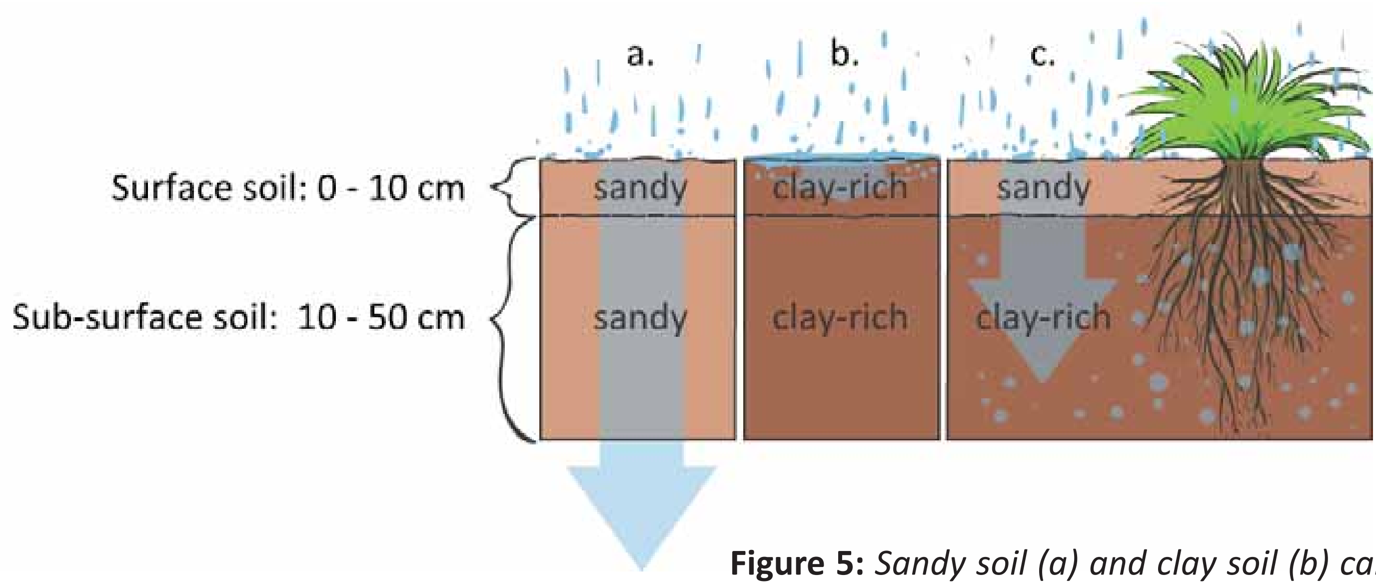


Figure 5: *Sandy soil (a) and clay soil (b) can absorb and hold less water than soil with a sandy surface and clay sub-surface (c).*

Slope and Landscape Position

Slope and landscape position affect site potential by affecting whether water soaks into the ground or flows over (and away from) the site. This affects soil moisture and plant productivity.

'Slope' refers to how steep the slope is at a site. Shallow slopes will have less runoff and higher potential than steep slopes.

'Landscape position' refers to where the site falls in the landscape relative to the topography around it. Is the site on the top of a hill or in a valley? Is it on a concave (bowl-shaped) slope, or on a convex (upside-down bowl-shaped) slope? This information will help to understand whether the site is collecting water or losing it as runoff. Sites that collect water (and where water is moving slowly so that it can infiltrate into the soil) have higher potential than sites that are losing water.

Figure 6, below, shows some of the possible landscape positions for a site. Generally, concave areas with shallow slopes have higher potential than convex areas and areas with steep slopes.

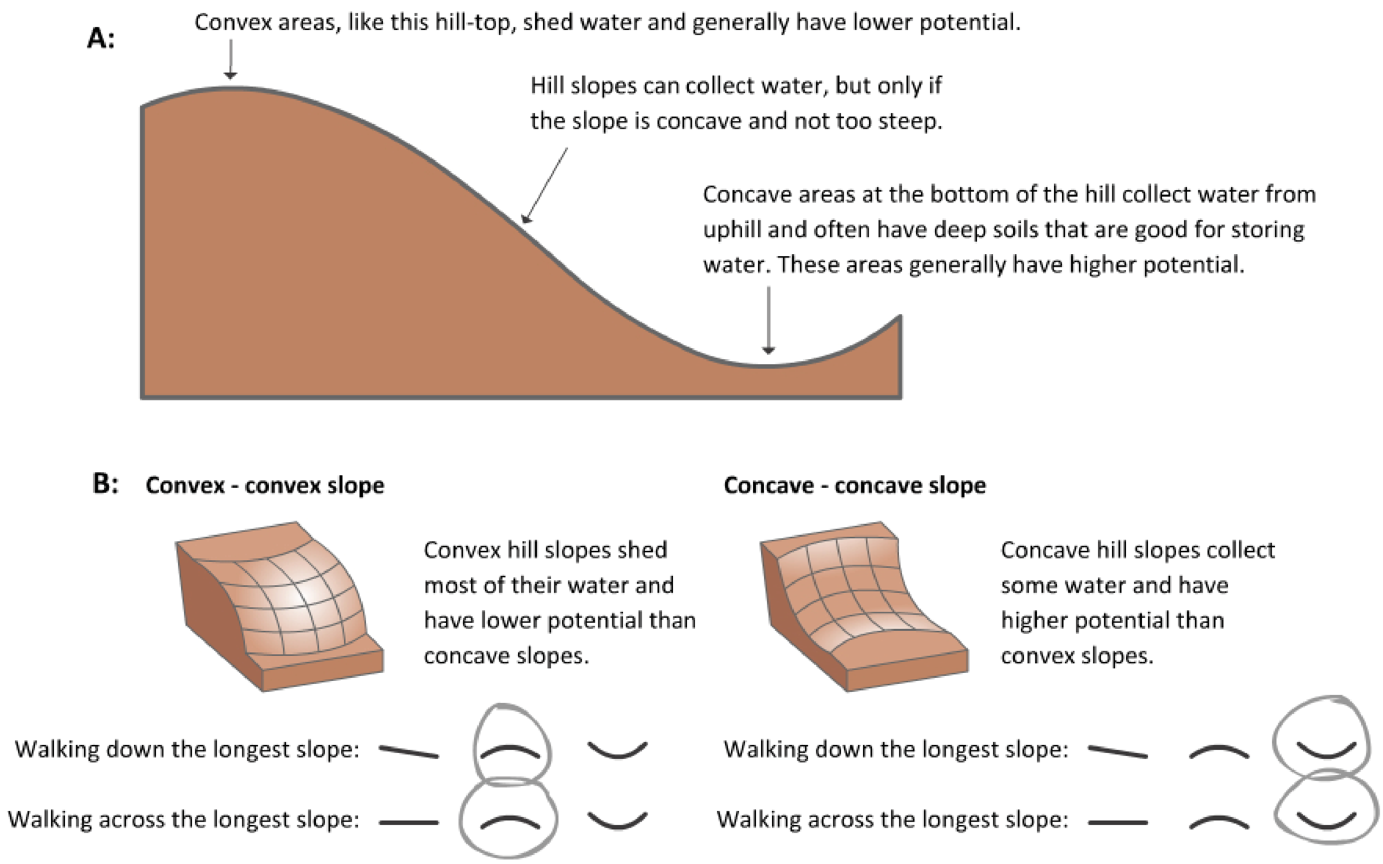


Figure 6: *The influence of landscape position (slope and slope shape) on site potential.*

Putting it together

The table below gives a general overview of the main factors to consider when estimating site potential. You can use this table to make a simple, rapid inventory of the potential of different types of land. In most arid and semi-arid lands, sites that absorb and hold water better will have higher potential.

Factor	Interpretation for site potential
Soil texture at the surface (0 - 10 cm)	Water soaks into soils with sandy surfaces faster than soils with clay surfaces, leading to higher site potential.
Soil texture below the surface (10 - 50 cm)	Clay soils, and mixtures of sand, silt and clay, hold more water than sandy soils, allowing plants to grow for longer and stay green longer into the dry season – leading to higher site potential.
Soil depth	Deep soils hold more water than shallow soils, leading to higher site potential.
Slope	Gentle slopes allow more water to soak in, leading to higher site potential.
Slope shape	Concave areas collect water better than convex areas, leading to higher site potential. Sites where the longest downward slope (from ridge top to valley bottom) is concave tend to have the highest potentials.

Fixed-Point Photographs

Photographs taken from the same place every year can show changes in the landscape structure and can provide a good visual record of other changes in the land. There are two types of fixed-point photographs: landscape photos and ground cover photos.

When taking either type of photo, be sure to include a piece of paper in the photo that indicates the site name and the date.

Landscape Photos

Landscape photos show the landscape as you would see it while looking out at eye level. They are most useful for monitoring changes in vegetation structure. It is important to take landscape photos from the same point and facing the same direction every year.

To take landscape photos:

1. Stand at the centre point of the monitoring site.
2. Face North. Use a compass, if you have access to one, to make sure that you are really facing North. This will help ensure that you face the same direction every year.
3. Place the piece of paper with the site name and date as well as the direction in which you will take the photo (North) in an upright position about 5 m North of the centre point so that you can see it clearly from the centre point. This paper can also be used as a scale if different types of cameras are used at different times.
4. Hold your camera over the centre point at a standard height and take the photo. You can use one of your monitoring sticks to take the picture from a height of 1 m every year.
5. Repeat this for each of the other three directions (East, South, and West).

Ground Cover Photos

Ground cover photos are taken vertically, pointing down at the ground. They are especially useful for monitoring changes in basal cover and the amount of bare ground (gaps) between plants. It is important to take the photo in the same place each year.

To take ground cover photos:

1. Walk 5 m North from the centre point of the monitoring site.
2. Mark off a small 1 x 1 m plot using your monitoring sticks or some string.
3. If this is the first time the plot is being photographed, mark the corners of the plot with something that will stay there permanently – for example, 10 cm nails.
4. Place the piece of paper with the site name and date, as well as the direction you walked from the centre point (North), just outside of the plot.
5. Hold your camera over the centre of the plot and take the photo.
6. Repeat this for two more permanently-marked 1 x 1 m plots at each monitoring site.

Soil Stability Test

The soil stability test measures the soil's stability, or resistance to erosion. It is a very sensitive indicator of land degradation. It is also valuable because it is less sensitive to short-term changes (e.g. due to drought) than other indicators like bare ground. Soil stability is usually higher when there is more organic matter in the soil. Soil stability is also affected by soil texture.

The simplest version of the soil stability test is the bottle-cap test:

1. Dig up a small soil fragment (a chip about 6-8 mm in diameter) and put it in a bottle cap that is filled with water.
2. Watch it for 30 seconds.
3. Gently swirl the water for 5 seconds.
4. Assign it one of these stability ratings:
    a. M = melts in the first 30 seconds (without swirling)
    b. D = Disintegrates when swirled (but does not melt)
    c. S = Stable (even after swirling)

Repeat the bottle-cap test at several locations within each monitoring site. An increase in soil stability over time means that the risk of erosion has decreased at that site.

Soil sample that has disintegrated after swirling it

Soil sample that has remained stable, even after swirling it

For a more sophisticated and accurate version of the soil stability test, see *Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems, Volume I* by Herrick et al. (See 'Additional Documents and Websites' on page 95 for the complete reference).

Alternative Methods for Plant Cover

For those who want to collect plant cover data in a more detailed or quantitative way, we suggest two alternative methods, the **line-point intercept** method and the **step-point transect** method. Both of these methods require you to periodically drop a thin, stiff wire (such as a bicycle spoke or a piece of brazing wire) to the ground and record the plants and ground cover features that the pin touches.

Line-point intercept

The line-point intercept method is a much more quantitatively rigorous and detailed way to collect cover data. This method requires that you lay out a tape measure along the ground and drop a vertical pin every 1 m along the tape. You can record all of the plants that the pin touches (dividing them into 'top canopy' and 'lower canopy') and the soil surface features that the pin touches (such as litter, moss, rock, bedrock, soil surface, etc.).

Step-point transect

The step-point transect method is very similar to the line-point intercept method except that you do not lay out a tape measure along the ground. Instead you drop a pin in front of your foot for every step that you take along an imaginary line. This method requires less equipment but is also less accurate than the line-point intercept method, since it is difficult to walk a straight line or to return to the same line every year.

Both of these methods are presented in more detail in *Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems, Volume I* by Herrick et al. (See 'Additional Documents and Websites' on page 95 for the complete reference).

Alternative Methods for Gaps Between Plants

For those who want to collect data on gaps between plants (both basal and canopy gaps) in a more detailed or quantitative way, we suggest two alternative methods, the **gap intercept** method and the **step-gap** method.

Gap intercept

The gap intercept method is a much more quantitatively rigorous and detailed way to collect data on plant gaps. This method requires that you lay out a tape measure along the ground and measure the size of every basal or canopy gap that is greater than a standard minimum length, such as 20, 30, 50, or 100 cm. Shorter minimum lengths provide more information but require more time.

Step-gap

The step-gap is a more simple method for collecting data on gaps. You do not need to lay down a tape to use this method; instead, you walk in a straight line and count the number of times that your entire foot falls within a basal or canopy gap. This method is less accurate than the gap intercept method since it is difficult to walk in a straight line or to return to the same line every year.

Both of these methods are presented in more detail in *Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems, Volume I* by Herrick et al. (See 'Additional Documents and Websites' on page 95 for the complete reference).

Annual plants: Plants that live only for one year. Since annual plants only come up after the rains, they are generally not reliable indicators of the land's ability to provide useful services (such as providing forage or controlling erosion).

Assessment: The process of evaluating rangeland health (i.e. how well critical ecological processes are functioning) at a particular site relative to the potential of that site.

Bare ground: Ground (soil) that has no dead or live plant material, lichen or other biological crusts, or rocks on or above it.

Basal cover: The percent of the ground (soil surface) that is covered by plant bases.

Base: See 'plant base.'

Biological crusts: Areas of the soil surface where lichens, mosses, algae, and cyanobacteria are growing. These organisms hold the soil surface together, giving it extra stability and preventing it from eroding. See also 'lichen.'

Erosion: Movement of soil or rock fragments by water or wind (often assisted by gravity).

Forbs or herbs: Non-woody flowering plants that are not grasses. Group perennial herbs with perennial grasses in your measurements of plant cover and gaps between plants, unless there are particular herbs that you want to record as 'key species' in the plant cover measurements.

Grasses: Plants with blade-like leaves that have their main growing point at ground level. The methods in this guide focus on perennial grasses, although you may also want to collect plant cover data on important annual grasses. Record important annual grasses as 'key species.'

Grass

Gully: A deep channel (> 50 cm deep) with steep sides through which water usually flows during rain storms. Gullies are usually created by erosion.

Indicator: Something easy and inexpensive, but often indirect, that you can measure to observe changes in rangeland health. Indicators are what you use to monitor the land.

Gully

Infiltration rate: The rate at which water soaks into the soil. Infiltration rate is higher where there is more organic matter in the soil.

Invasive plants: Plants that are spreading quickly across the landscape. Often they are exotic or, if native, were once uncommon in the landscape. Invasive plants have the potential to become dominant if their establishment and growth are not controlled by management.

Inventory: The process of gathering information about the resources and features of the land being managed and monitored. Completing an inventory is useful for planning your management and monitoring programs.

Land managers: All the people, including community members, who make decisions that have an impact on the land. This could include day-to-day decision-makers as well as decision-makers who may be more removed from the daily activities.

Litter dam

Landscape: An area of land – which can include different types of land – that is connected by the movements of plants, animals, and water.

Landscape position: Where a site is situated in the landscape – for example, in a valley at the bottom of a hill, on a hill slope, or on a hill-top.

Lichen: Very small organisms that grow just on the surface of the soil, making the soil look black on the surface. When recording plant cover, record all types of biological crusts that are visible on dry soil (including algae, mosses, and cyanobacteria) as 'lichen.' See also 'biological crusts'.

Lichen

Litter: Dead plant material that is not attached to the plant anymore. This could include leaves, sticks, branches, or any other dead plant material.

Litter dam: Litter that has been pushed together into a clump by flowing water.

Management: Any actions (or lack of actions) that have an impact on the land.

Monitoring: In this guide, 'monitoring' means the systematic and orderly collection, analysis, and interpretation of information about changes in rangeland health over space and time. Monitoring is used to determine whether your management is having the effects you intended or anticipated.

Monitoring area: A general area you have designated for monitoring. Each monitoring area should be defined by the combination of type of land and management system. If you are monitoring specific, targeted areas, each target area should be a separate monitoring area. Otherwise, each monitoring area should be defined by the combination of type of land and management system.

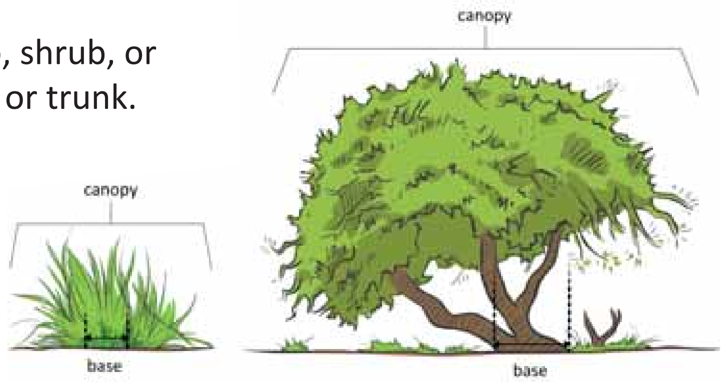
Monitoring site: The specific sites at which you collect monitoring data. Each monitoring area should have several specific monitoring sites in it.

Organic matter: Decomposed plant and animal material. Soils with more organic matter in them are less vulnerable to erosion, have higher infiltration rates, and have more nutrients in them.

Pedestals

Pedestals: Plants or rocks that are 'standing up' above the soil surface because the soil around them has been eroded away.

Perennial plant: Plants that live for many years. Since perennial plants are present even during the dry season, they are generally good indicators of the land's ability to provide useful services (such as providing forage or controlling erosion).



Plant base: The part of the plant (grass, herb, shrub, or tree) that is rooted to the ground – the stem or trunk.

Plant canopy: The part of the plant (grass, herb, shrub, or tree) that is above the ground – everything but the base.

Plant cover: The amount of ground (soil surface) that is covered by a base, leaf, stem, or branch of any perennial plant.

Potential (site potential): The condition of the site (including biomass production) under the best possible circumstances; what is possible at a site if it is well-managed. Site potential varies depending on climate, soil, and landscape position.

Physical crusts: Areas of the soil surface that have sealed together. Physical crusts are formed when raindrops hit bare soil, breaking the soil apart and letting it re-seal to form a hard 'cap'. Physical crusts have low infiltration rates and lead to a high level of runoff.

Restoration: The process of assisting the recovery of a degraded, damaged or destroyed landscape. In arid and semi-arid lands, this is often accomplished through interventions aimed at stopping erosion and improving plant cover.

Rills: Small gullies; small water channels with steep sides (< 50 cm deep), usually caused by erosion.

Rill

Sedges: Plants that look like grasses but have triangular stems. Group perennial sedges with perennial grasses when collecting data on plant cover or gaps between plants.

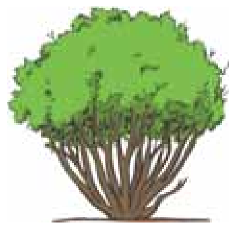
Seedlings: Young plants. Seedlings of shrubs and trees are usually small (< 30 cm high). Use local knowledge to help differentiate between young plants and plants that are short but not young.

Sheet erosion and teracettes

Sheet erosion: Erosion that carries away layers of soil without forming channels (rills or gullies). Sheet erosion may leave behind signs such as plants on pedestals, exposed bedrock, small rocks on the soil surface, accumulations of sand, and small 'steps' (teracettes) going down the slope on the soil surface.

Shrubs: Woody plants of species that never grow tall (usually the largest individuals are less than 2 m tall). Use local knowledge to help differentiate between trees and shrubs.

Soil deposition: Soil that was eroded from one area and has now been deposited in a new area by either water or wind.

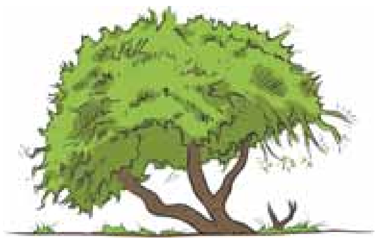


Shrub

Succulents & cacti: Succulents are plants that hold water in their leaves or stems. These include native succulents, such as aloes, euphorbias, and sansevierias, as well non-native succulents such as the *Opuntia* cacti.

Topography: The shape of the landscape, including information about hills and valleys, and how large or steep these hills and valleys are.

Trees: Woody plants of species that can grow tall (usually the largest individuals are more than 2 m tall). Use local knowledge to help differentiate between trees and shrubs. Seedlings of tree species should be called 'trees,' not 'shrubs.'



Tree

Type of land: Types of land or 'ecological sites' are defined by the combination of soil type, topography, and climate. Different ecological sites have different potentials to produce forage and respond differently to management.

Many of these documents are available from the authors of this guide upon request.

Inventory and Assessment (Including Participatory Mapping)

Esler, K.J., Milton, S. J. and W. R. J. Dean. 2007. *Karoo Veld: Ecology and Management.* Pretoria, South Africa: Briza Press.

Irwin, B. and F. Flintan, forthcoming. *Guidelines for Practitioners: Rangeland Resource Mapping.* Addis Ababa, Ethiopia: ELMT-USAID/East Africa.

Pellant, M., P. Shaver, D. Pyke and J.E. Herrick. 2005. *Interpreting Indicators of Rangeland Health, Version 4.* Interagency Technical Reference 1734-6. Denver, CO, USA: Bureau of Land Management.
http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm

SOS SAHEL Ethiopia. *Participatory Field Methods: Participatory Pastoral Resource Mapping*. Technical Support Programme Report for Save the Children US – Pastoral Livelihoods Initiative Consortium.

Planning & Setting Management Objectives

King, J., G. Parker, and D. Lesimirdana. 2009. *Developing Participatory Rangeland Monitoring and Management.* Report by Northern Rangelands Trust and Marwell Wildlife.

Savory, A., and J. Butterfield. 1999. *Holistic Management: A New Framework for Decision Making.* Washington, DC, USA: Island Press.

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http://www.iied.org/pubs/pdfs/12562IIED.pdf

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ftp://ftp.fao.org/docrep/fao/011/i0821e/i0821e.pdf

Participatory Monitoring and Evaluation

Feuerstein, M. 1986. *Partners in Evaluation: Evaluating Development and Community Programmes with Participants*. London, UK: Macmillan Education Ltd.

Germann, D. and Gohl, E. 1996. *PIM Booklet 1: Group-Based Impact Monitoring*. Participatory Impact Monitoring series. Eschborn, Germany: GTZ.
http://www2.gtz.de/dokumente/bib/96-2007_I.pdf

Gujit, I. 1999. *Participatory Monitoring and Evaluation for Natural Resource Management and Research*. Socio-economic Methodologies for Natural Resources Research. Chatham, UK: Natural Resources Institute.

Waters-Bayer, A. and Bayer, W. 1994. *Planning with Pastoralists: PRA and more - a Review of Methods Focused on Africa*. Eschborn, Germany: GTZ.
http://www2.gtz.de/dokumente/bib/95-0400.pdf

Ecological Monitoring Methods

Monitoring and Assessment Website:
http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm :
The Jornada Experimental Range Monitoring and Assessment website includes downloadable versions of this guide, *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems*, *Interpreting Indicators of Rangeland Health*, as well as other resources such as:

- Sample-size calculator
- Training videos for several of the alternative monitoring methods (pages 87-90)
- User-friendly databases that can be used to collect and store information

Rangeland Monitoring and Assessment Methods Guide:
http://www.rangelandmethods.org/
This on-line guide includes a selection tool for both field-based and remote sensing monitoring and assessment methods, and links to additional resources.

Elzinga, C.L., D.L. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. *Monitoring Plant and Animal Populations.* Malden, MA, USA: Blackwell Scientific.

Herlocker, D. 1995. *Range Resource Monitoring: Field and Office Guidelines.* Range Management Handbook of Kenya, Volume III, 10. Nariobi, Kenya: MALDM/GTZ Range Management Handbook Project.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L. M. Burkett and W.G. Whitford. 2005. *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems.* USDA-ARS Jornada Experimental Range, Las Cruces, NM, USA: University of Arizona Press.
http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm

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Notes

USAID
FROM THE AMERICAN PEOPLE

MPALA
THE MPALA RESEARCH CENTRE &
THE MPALA WILDLIFE FOUNDATION

PRINCETON UNIVERSITY

USDA ARS Agricultural Research Service

DENVER ZOO

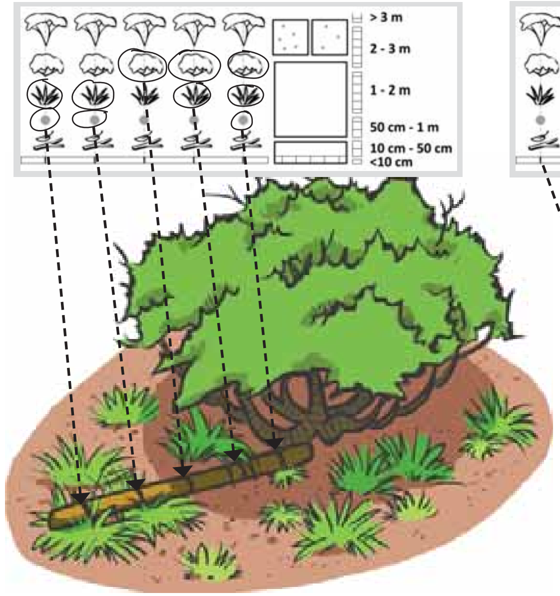
USGS
science for a changing world

ACC
AFRICAN CONSERVATION CENTRE

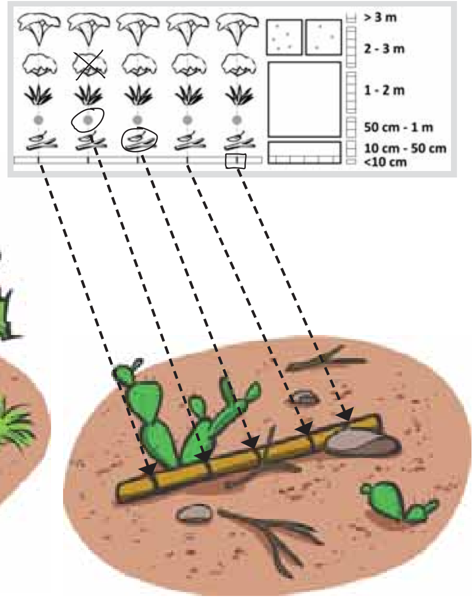
BASECAMP FOUNDATION

VSF VÉTÉRINAIRES SANS FRONTIÈRES SUISSE

Plant and ground cover (cover of trees, shrubs, grasses, plant bases, litter, rock, lichen, and bare ground)



'Good' grass and shrub cover and plant bases.



'Bad' shrub cover, litter, rock, and bare ground.

Instructions:

Record plant and ground cover at each mark on one edge of the stick:

1. Draw a box over the stick mark if the mark is on top of a rock or stone (must be > 5 mm in diameter).
2. Draw a V over the stick mark if the mark is on top of lichen.
3. Circle the litter symbol if the mark is on top of unattached, dead plant material.
4. Circle the plant base symbol if the mark is over or along a plant base. Also circle (or X) the canopy symbol for that type of plant.
5. Record canopy cover at each mark. Draw a circle for 'good' plant species and an X for 'bad' plant species:
    a. Circle or X the grass canopy symbol if the mark is over or under a perennial grass or forb leaf or stem.
    b. Circle or X the shrub canopy symbol if the mark is under shrub leaves, stems, or branches.
    c. Circle or X the tree canopy symbol if the mark is under tree leaves, stems, or branches.

Gaps > 1 m Between Plant Bases and Plant Canopies

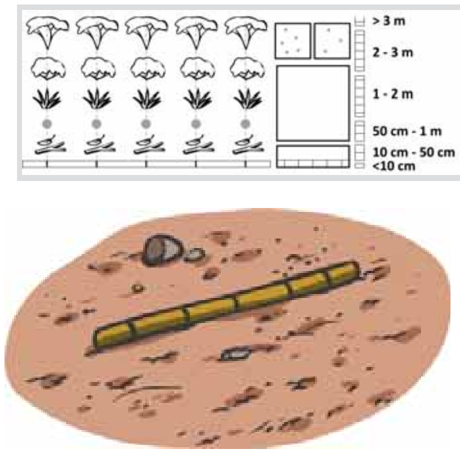
Instructions:

Gaps > 1 m Between Plant Bases

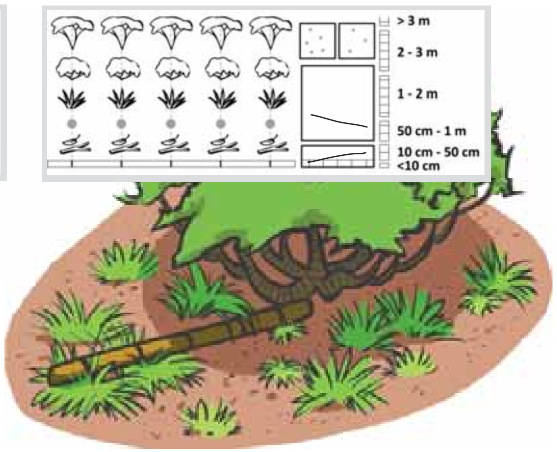
- If the stick touches any kind of plant base anywhere along the stick, make a mark through the bottom gap box to indicate that the gap is broken.
- If there is no plant base anywhere along the stick, leave the bottom box empty to indicate that there is a gap > 1 m between plant bases

Gaps > 1 m Between Plant Canopies.

- If there is a plant canopy anywhere over the stick, make a mark through the top gap box to indicate that the gap is broken.
- If there is no plant canopy anywhere along the stick, leave the top gap box empty to indicate that there is a gap > 1 m between plant canopies.
- Record only plant canopies between 10 cm and 2 m in height.



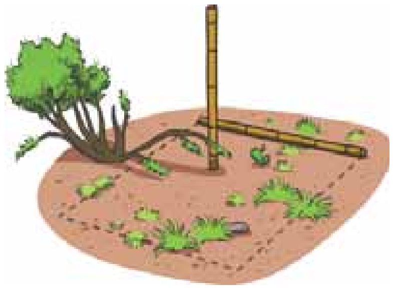
No plant base or plant canopy anywhere along the stick. Do not mark either box.



Plant bases and plant canopy along the stick. Mark both boxes.

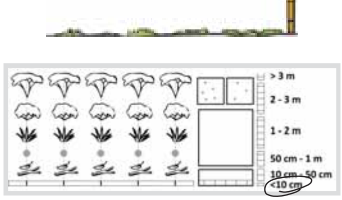
Plant Height

Instructions: Estimate the height of the tallest plant part (branch, leaf or stem) that is inside a 1 x 1 m box in front of the stick. On the datasheet, circle the height class that describes the height of this plant part.

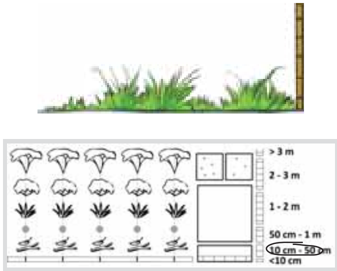


Estimate the height of the tallest plant part in the 1 x 1 m box, even if the plant is rooted outside the box.

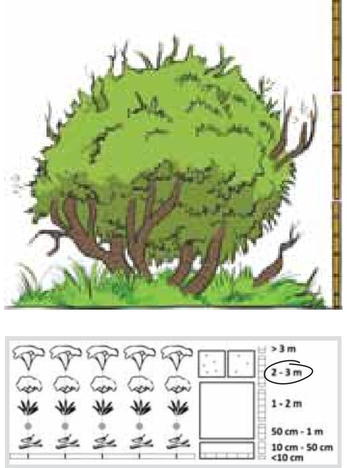
Plant less than 10 cm tall



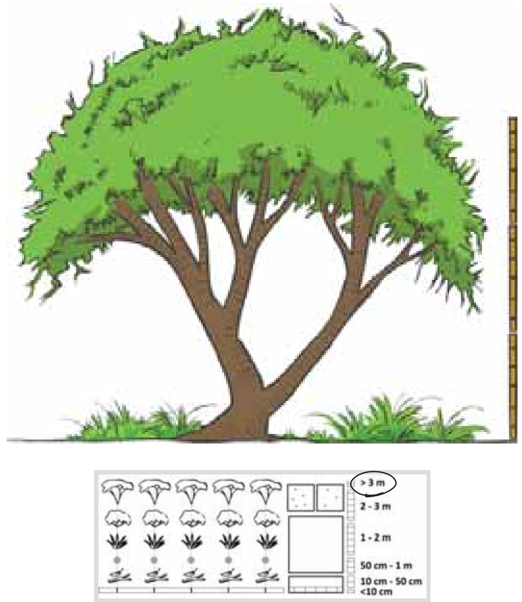
Plant 10 cm - 50 cm



Plant 2 - 3 m

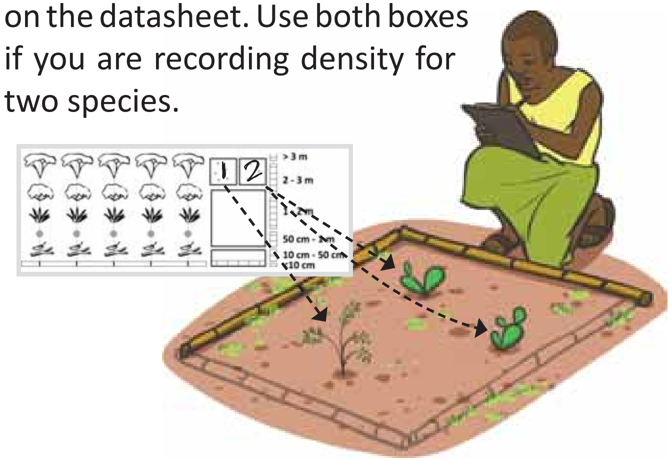


Plant more than 3 m tall

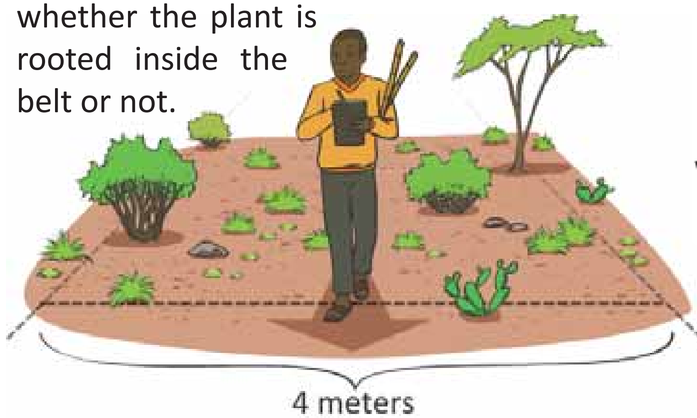


Plant Density

Option 1: Twenty small plots
Use two sticks to make a square plot (1 x 1 m). Count the number of plants in the plot and record this number in one of the small boxes on the datasheet. Use both boxes if you are recording density for two species.



Option 2: Four belt transects
Walk in a straight line along each of the four 20 m transects, counting the number of plants that are rooted within 2 m on each side of you. Use the sticks to help determine whether the plant is rooted inside the belt or not.



Option 3: One big plot
Mark out one large plot, with the transect ends as corners. Count the number of plants that are rooted within this plot.